THE RELATIONSHIP BETWEEN ENVIRONMENTAL CHARACTERISTICS AND INVASIVE FISH SPECIES IN SELECTED TRIBUTARIES WITHIN THE CLEAR LAKE WATERSHED DURING SUMMER MONTHS

BY

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Master's Project

Presented to the Faculty of

The University of Houston Clear Lake

In Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE

THE UNIVERSITY OF HOUSTON CLEAR LAKE

July, 2008

Acknowledgements:

We would like to thank TPWD Regional Director Lance Robinson for his initial input during the design phase of our study and for providing us with data collected during their study. Family, friends, and other volunteers, as well as the numerous students that helped collect and identify these samples including Kelli Haskett, Julie Sandefur, Mike Franks, Heather Houlihan, Sara Boroque and students enrolled in the UHCL Biology of Fishes and Marine Biology courses. I also would like to thank Heather Biggs for creating the site map and land use map utilized within this paper. I would like to thank my advisor Dr. George Guillen for his guidance and assistance throughout the project. I also would like to thank Dr. Cynthia Howard for her review and suggestions during preparation of my proposal and paper.

Abstract

The introduction of invasive species into the United States has become a major environmental and economic problem. The presence of invasive species in smaller, nonnavigable streams in the Clear Lake watershed has not been investigated. The main goal of this study was to determine which environmental conditions have a significant relationship with the composition of the fish community in selected smaller, wadeable tributaries, within the Clear Lake watershed. The first objective of this study was to examine the relationship between water quality and invasive fish species. The second objective of this study was to examine the relationship between invasive fish and native fish by comparing invasive fish abundance and native fish abundance. Rio Grande cichlids (*Cichlasoma cyanoguttatum*) and Tilapia (*Oreochromis spp.*) were collected from all streams sampled. Rio Grande cichlids and Tilapia were the 5th and 8th most abundant species collected. Due to the abundance of Rio Grande cichlids, a range extension is suggested to include the Clear Lake watershed. The presence of invasive cichlids for seine collections was negatively correlated with overall fish community diversity, and evenness; whereas the presence of the invasive cichlids was negatively correlated with fish community diversity, evenness and richness for the electroshocking samples. The streams within the Clear Creek watershed had higher centrarchid abundances and higher fish community richness than those in the Armand Bayou watershed.

Introduction

The introduction of invasive species into the United States has become a major environmental and economic problem. Invasive species can displace native species through competition and predation (Herbold & Moyle, 1986 & Taylor, et al 1984). Intentional releases of invasive species have previously occurred due to a lack of knowledge about the negative effects that the invasive species have on the surrounding environment and native organisms. Stocking of ornamental and game species has led to widespread establishment of many invasive species. Furthermore, unintentional and illegal releases increase the chance that many more invasive species will become established. Urbanization, in addition to other human disturbances, can disturb natural habitat, resulting in alterations to the environment. Potential stressors include the release of wastewater effluent from sewage treatment facilities and industries that can increase stream temperatures, nutrients, and algal growth. These alterations can create new environments in which invasive species are better adapted, allowing invasive species to thrive at the expense of native species (Kennard et. al, 2005 & Brasher, 2003). In order to manage and protect our natural resources it is imperative that we gain a better understanding of the relationship between invasive species and their habitat.

Coblentz (1993) suggests that due to the effects invasive species have on the environment; once an invasive species is introduced the native species will eventually become extirpated or extinct. Introduction of invasive species is second only to habitat degradation in causes for extinction of native species.

Two major regulatory approaches have been established to combat the increasing problem of invasive species' introduction into the United States. The main tool that the U.S. government uses to reduce the introduction of invasive species is the Lacey Act. The Lacey Act

(16 USC 3371-3378), passed in 1900, supports other U.S. and state laws by making it illegal to possess, purchase, sell, import, or export any fish that is restricted by any state or federal laws. In addition, the Lacey Act forbids the import of animals listed within the Lacey Act or declared by the Secretary of the Interior to be injurious to man, agriculture, or wildlife resources. Depending on the monetary value of the wildlife, violations are either a felony or misdemeanor, each of which is penalized with fines. The Lacey Act provides for enforcement as well. Enforcement for violations includes warrants, arrests, and ability for enforcement officers to use firearms.

The second, and most recent regulatory approach, was executive order number 13112 (1999) issued by President Clinton. This order established the Invasive Species Council, consists of presidential cabinet members, as well as experts in areas that can assist the council. The purpose of this council was to oversee implementation of regulations, to disseminate information and to create and implement an invasive species management plan.

Individual states also regulate the transportation of invasive species through state administrative codes and statutes. Texas statutes, or state laws, that help reduce the likelihood of introduction of invasive species include the agriculture code which includes regulations that involve the inspection, labeling and sale of agriculture and vegetable seed, the Mexican fruit fly control, fire ant control and establishment of noxious weed control districts. Also under the state statutes is the natural resources code which regulates forest pest control. The Texas administrative code, or state agriculture regulations, includes the Boll weevil eradication program, quarantines, and the natural resources and conservation regulations which includes fisheries. The fisheries regulation is divided into multiple categories dealing with 1) harmful or potentially harmful exotic fish, shellfish, and aquatic plants, 2) the introduction of fish, shellfish and aquatic plants, and 3) aquatic vegetation management (http://tlo2.tlc.state.tx.us/statutes/ag.toc.htm & http://info.sos.state.tx.us/pls/pub/readtac$ext.ViewTAC?tac_view=3&ti=4&pt=1).

Species that have recently arrived in an ecosystem are referred to by many names, including exotic, invasive, alien, introduced, and translocated. Executive Order 13112 (1999) defines an invasive species as a "species whose introduction does or is likely to cause economic or environmental harm or harm to human health". This paper will use this definition of invasive species.

A number of vectors and pathways exist by which invasive species can be introduced. Invasive fish in particular, have been introduced in a variety of ways, including unintentional releases from ship ballast, poor practices in aquaculture facilities, and release of aquarium fish by hobbyists and pet stores. Canal and aqueduct development can also lead to unintentional spreading of invasive species. This was documented after construction of the Welland Canal in the Great Lakes which allowed the lamprey and numerous other fish to invade. Intentional releases of invasive species are also initiated for biological control, as with grass carp (*Ctenopharyngodon idella*), and recreational purposes such as sport fishing. The nonnative species may also be introduced as a food source, such as common carp (*Cyprinus carpio*), or even for species preservation and restoration, which is the case for various cyprinid species. For example, numerous cyprinid species have been stocked for sport fishing enhancement and bait. These introductions were often conducted without regard for future impacts. Even when environmental impacts were assessed, they were not considered negative if the effects did not impact sport fish or commercially important fish. (Courtenay, 1993)

The introduction of invasive species has, for many years, been an accepted practice dating back to the Roman Empire when common carp were used in canals to reduce vegetation and goldfish were used as ornamental fish in ponds (Welcomme, 1984). There have been three major periods of introductions of fish across the world. The first wave of introductions occurred during the European Middle Ages when people slowly started voyaging to new areas. Although this did not account for the largest number of species introduced, this first wave created a major impact in terms of the distribution of species present today, especially in Asia. The second period was in the mid-19th Century as European colonialism increased. At that time, the fish were transported more for "sentimental" value than anything else and were transported with humans as they traveled to new unfamiliar locations. The last wave of introductions occurred after World War II, when the use of jet cargo planes led to a decrease in transportation times. As a result of this more reliable, faster transportation, a wider variety of species, including the more sensitive species, such as aquarium fish, could successfully be transported across the world. This has resulted in international and intranational introductions (Courtenay, 1993).

As a result of these introductions, approximately 4,500 invasive species were reported in the U.S.A. in 1991 (OTA, 1993). Pimentel et al. (2000) found that the number of invasive species in the U.S.A. had increased to 50,000, of which at least 138 species were fish. These introduced species make up 8% of the fish species in the U.S.A. As human commerce and travel increases, so do the opportunities for fish species to spread and become invasive.

Invasive species affect many components of the ecosystem into which they are introduced. Invasive fish simplify food webs of the area through predation on and competition with native fish. This simplification, in turn, often reduces the total number of fish species.

Hybridization may also occur, especially within cichlids, which reduces the genetic integrity of both the native and exotic fish (Taylor, et al, 1984).

Adverse spatial interactions including excessive aggression and overcrowding are often caused by the introduction of an invasive species. These aggressive effects have been documented by Traxler and Murphy (1995). They observed competition based on differential growth, Tilapia growth rates increased whereas large mouth bass (*Micropterus salmoides*) growth decreased when caged together. Competition also occurred with diet changes between tilapia and large mouth bass. Large mouth bass would shift diets in the presence of tilapia.

Invasive species can contain parasites and diseases that may adversely affect native fish. Asiatic tapeworm, which has been found in grass carp and other fish species, can kill native fish because they are not adapted to it. Whirling disease, which was brought to the U.S. by non-native trout, affects Salmonid fish species and has caused loss of wild rainbow trout recruitment in many rivers (Graff, 1996 and Bergersen & Anderson, 1997). Another example is the gill trematode which affects many species of fish including centrarchids. Some invasive fish species that are found in Texas, such as blue tilapia (*Oreochromis aureus*), redbelly tilapia (*Tilapia zilli*), green swordtail (*Xiphophorus helleri*),and goldfish (*Carassius auratus*) have been known to host the gill trematode. (Mitchell, et al., 2005)

Digging by invasive species during foraging and nesting causes siltation and can increase stream turbidity that can degrade water quality. Turbidity increases are often observed in the presence of loricariid catfish and carp due to this behavior. Uprooting of plants by invasive fish decreases the amount of stream vegetation. Many species, especially centrarchids (sunfish), use vegetation as cover for spawning and to avoid predation. Invasive fish can also affect water quality at high densities by producing increased organic wastes that lead to eutrophication and phytoplankton blooms (Taylor et al, 1984; Welcomme, 1984).

Invasive species not only have ecological effects; they have economic effects as well. According to the Office of Technology Assessment (1993) from 1906-1991 invasive species had documented impacts costing 97 billion U.S. dollars. A more recent study conducted by Pimentel et al. (2000) suggests that the annual economic cost for the control and effects of invasive species is closer to 137 billion U.S. dollars. The shear numbers of invasives, as well as the impact that invasive species can have, make them of major concern both economically and environmentally.

Certain characteristics make an introduced species more likely to become invasive. Stauffer (1984) suggests that invasive species are preadapted to environmental conditions in the areas in which they become established. Characteristics used by Kolar and Lodge (2002) to assess the potential of a fish species to become established include temperature range, salinity range, growth rate, relative growth, diet breadth, and the species' history of invasiveness. Howells and Garrett (1992) used similar characteristics including salinity range, temperature tolerance, wide habitat range and predatory nature to assess the invasive potential of Nile perch (*Lates spp.*). They concluded that Nile perch should not be stocked in Texas.

Kolar and Lodge (2002) described how a species can be transported to and become established at a new location through the sequence of steps that includes 1) transportation to the site, 2) introduction to an area, and 3) establishment. When the species becomes established, the invasion enters the spread stage. Once the invasive species has begun to spread, it can become a nuisance. To reach this established stage, species need to exhibit a fast growth rate and wide temperature and salinity ranges. Taylor, et al. (1984) include having broad tolerances for low oxygen levels, turbidity, pollution and drought as factors that further determine if a species will become invasive. Kolar and Lodge (2002) also state the need for stage specific, taxon specific and ecosystem specific quantitative analyses in order to predict which species are most likely to become invasive.

Feeding habits and vulnerability to predation, as well as the species' reproductive behaviors, such as lengthened or continuous breeding, multiple broods and advanced parental care, have also been found to influence the invasiveness of a species (Taylor et al, 1984). Cichlids possess these types of increased reproductive and survival strategies. This increased ability to survive allows cichlids to become invasive and compete with native fish including centrarchids (Stauffer, 1984).

Welcomme (1984) found that the number of endemic species will have an effect on whether or not an invasive species becomes established. Gido and Brown (1999) further suggest that the number of native fish species has an effect on the ultimate number of invasive fish species. They concluded that high numbers of native fish decrease the probability that an invasive fish will become established. Therefore, fewer invasive species will be present in areas with high numbers of native fish.

Invasive fish species are more likely to inhabit disturbed waterways than natural waterways. When considering the consequences from a large geographic scale, such as the western United States, the number of invasive species increases with the amount of human disturbance, such as the disturbances that occur in urban areas (Meador et al, 2003). Welcomme (1984) states, that when ecosystems have been overfished or have gone through environmental modifications those ecosystems are more likely to support invasive species. Increases in invasive species richness were found by Meador et al (2003) to be related to increases in human population density. Kennard et al (2005) found that invasive species had higher relative abundance in areas that had been degraded, particularly by human disturbance. Urbanized areas may therefore increase the probability of an introduced species becoming invasive.

Invasive species tend to live in waters where conditions create stress for native fish. Therefore, tolerance of the invasive species to the environmental extremes of the urbanized areas, results in the invasive species experiencing less stress than the native species. In a study comparing environmental conditions and invasive fish, Meador et al. (2003) collected surface-water samples from river basins in the United States. Seven river basins in the western U.S. were sampled, including the Rio Grande in Texas. They evaluated various factors including suspended sediment, total nitrogen, total phosphorus, pH, dissolved oxygen, dissolved organic carbon, water temperature, discharge and specific conductance. After analyzing their data using Pearson correlation and regression analyses, Meador et al. (2003) determined that in the western rivers increased total nitrogen, total phosphorus and temperature were related to the number of invasive fish present.

Lau et al. (2006) have determined that changes to habitat can affect the fish assemblage structure and quality. As streams are channelized the natural variation (i.e. pool, riffle, run complexes) in habitat is lost. During channelization, not only are streams straightened, disturbing this natural habitat, but often the substrate is altered and instream cover is removed. Four factors responsible for the affects on fish assemblages are 1) quality of pool, riffle, run complexes 2) substrate 3) channel morphology and 4) instream cover. Overall channelization has a negative influence on fish assemblage.

Through intentional and accidental releases, species that are not endemic have found their way into the southwestern United States. Invasive species that have been found in Texas include

Rio Grande cichlids (*Cichlasoma cyanoguttatum*), blue tilapia (*Tilapia aurea*) , Mozambique tilapia (*T. mossambica*), Nile tilapia (*Oreochromis niloticus*), redbelly tilapia (*T. zilli*), common goldfish (*Carassius auratus*), guppy (*Poecilia reticulata*), green swordtail (*Xiphophorus helleri*), armored catfish including snow plecostomus (*Pterygoplichthys anisitsi*) and *Hypostomus* species, grass carp (*Ctenopharyngodon idella*), and common carp (*Cyprinus carpio*) (Robinson and Culbertson, 2005; Nico and Martin, 2001; Martin, 2000; Courtenay et al, 1984). Although Rio Grande cichlids are native to the Rio Grande River watershed in Texas they have been introduced to areas outside their native range.

Invasive fish have been found within Texas, in urban areas including the Greater Houston area. Grass Carp were used to stock Lake Conroe in 1981-1982. Trimm et al (1989) collected and analyzed data on grass carp within the Galveston Bay watershed from 1983- 1987 and concluded that the grass carp had probably escaped from Lake Conroe. During the periods from 1995-1996 and 2001 – mid-2003, Texas Parks and Wildlife Department (TPWD) Law Enforcement and Inland Fisheries Division recorded seizures from violations of TPWD invasive species regulations within Harris County, Texas. The time gap is due to law enforcement being diverted to other violations and not of compliance with invasive species regulations in Harris County. During this time period, 557 illegal fish were found in food markets, pet stores, and with individual aquarists within greater Houston, Texas. Among the illegal fish were various cichlids including six blue tilapia (*T. aurea)* (Howells and Rao, 2003). In November 2006, 100 tilapia were found dead in a tributary to Horsepen Bayou, (W. Denton, pers. comm.). Tilapia have also been reported in Clear Creek during December 2006 (J. Culbertson, pers. comm.). Texas Parks and Wildlife code regulations prohibit all species of tilapia, including the genus *Oreochromis,* from being imported, possessed, sold or placed into Texas waters (TPWD, 2001). Tilapia are very popular aquarium and food fish that are frequently released. In addition, *Pterygolichtes anisitsi* (snow plecostomus), an armored catfish species, has been reported in Dickinson Bayou and will be added to the watershed's invasive species list (J. Culbertson, pers. comm.)

Invasive fish species found to have reproducing populations in Texas and other Gulf Coast states, exhibit the following traits or characteristics of concern. Armored catfish, both *Hypostomus* sp. and *Pterygoplichthys anisitsi* (snow plecostomus), can cause siltation due to burrowing. Armored catfish often compete with native species for food and space. The minimum temperature tolerance of armored catfish is unknown, although their native temperature range is 1°C to15.4°C. Armored catfish have been found in thermal refuges created by the discharge plumes from sewage treatment plants in urban streams in Texas. This observation suggests that natural water temperatures in Texas are below their preferred temperature (Nico & Martin, 2001). In Mississippi, Nile tilapia (*O. niloticus*) inhabited aquaculture effluents as refugia, because the temperature in the effluent stream was never below 15.1°C. The effluents also have increased conductivities. At higher levels of dissolved solids and conductivities, this species tolerance to low temperatures is enhanced. Nile tilapia breed at a young age, possibly as early as the first summer after being spawned. In the Pascagoula River, Mississippi, Nile tilapia spawn year round (Peterson et al. 2005). Urban areas in Texas have many wastewater discharges that Nile tilapia may be able exploit in the same manner.

Summer temperatures in the lower Galveston Bay watershed may reach levels that are stressful to native fish. When fish are stressed it often reduces their ability to compete. Martin (2000) observed that the Rio Grande Cichlids in Sims Bayou, located in Harris County, Texas, had a seasonal distribution with increased numbers beginning in April or May with subsequent declines during cooler weather starting in November and December. Based on these observations, the numbers of cichlids are expected to increase and the numbers of native sunfish are expected to decrease during the summer months. To test this hypothesis it is necessary to monitor native sunfish abundance during summer months in the presence and absence of Rio Grande Cichlids. Furthermore, long term studies that evaluate the seasonal response to invasive species including Rio Grande cichlids would help to better define potential mechanisms of dispersal and competition.

Given the breadth of the problem, it is surprising that so little research has been conducted on invasive fish species within Texas. Robinson and Culbertson (2005) conducted a study on invasive species within selected bayous of Galveston Bay in navigable coastal waters from April 2004 to February 2005. The purpose of the study was to assess the total fish diversity and quantify the invasive species within Brays Bayou, Buffalo Bayou, and Green's Bayou of Galveston Bay. The following six invasive fish species were found in the selected bayous: Rio Grande cichlid, snow plecostomus, blue and Nile tilapia, grass carp and common goldfish. While this study examined invasive species in bayous, the authors suggested that secondary and tertiary streams should be studied to determine the fish diversity and extent of invasive species in the smaller waterways.

Preliminary unpublished survey data collected in the Clear Lake watershed has documented the presence of invasive species, including snow plecostomus, Rio Grande cichlids and Nile tilapia, in first and second order streams (Guillen pers. comm.). However, a comprehensive study of the smaller, nonnavigable streams in the Clear Lake watershed has not been conducted. This is due to the fact that no resource management agency routinely monitors these water bodies. Currently Texas Parks and Wildlife Department (TPWD) only monitors open bay and freshwater reservoirs on a routine basis. Therefore, little is known about the diversity and abundance of invasive species, let alone their impact in these smaller waterways.

Omerod (2003) identified the need for more publication of research on invasive fish. He states that many articles have recently been published on terrestrial invasive species, whereas there have been very few articles published on aquatic species. Considering the economic and environmental problems associated with invasive species, insufficient research is being conducted to address these problems.

Meador et al. (2003) also state the need to determine which physical and chemical stream characteristics are common in streams that are inhabited by invasive species. Knowing these stream characteristics will improve the current understanding of the impacts of invasive species. If predictive models can be developed using the relationship between stream characteristics and invasive species resource managers may be able to reduce the negative impacts associated with invasive fish species by wise habitat and water quality management.

The primary goal of this study was to determine the relationship between environmental characteristics and invasive fish species in selected tributaries within the Clear Lake watershed, part of the Galveston Bay system. The first objective of my study was to examine the relationship between water quality and invasive fish species. To accomplish this objective the physical, hydrological and water quality characteristics of these streams were measured to determine the relationship between water quality characteristics and invasive fish abundance. The second objective of my study was to examine the relationship between invasive fish species and native fish species. To accomplish this objective I compared invasive fish abundance to native sunfish abundance, total number of native fish species, total native fish community abundance, and fish diversity indices. I also evaluated the influence of invasive species on overall fish community composition. In addition, I compared the average body size of native fish from areas with and without invasive fish. Comparing the average body sizes enabled me to determine if invasive fish in the selected tributaries may be affecting the size of the native fish in those tributaries through direct or indirect competition for resources.

My first research hypothesis is that invasive fish species are found in greater numbers in degraded versus minimally degraded streams. Degradation will be determined by the amount of wastewater loading near the site, surrounding land use, and measurement of selected water and habitat variables. The degraded waterways are expected to have an increased amount of invasive fish and a decreased amount of native fish compared to the minimally degraded waterways. Therefore, the composition of the fish community in the degraded tributaries is expected to differ from the fish community in the natural or minimally degraded tributaries.

My second research hypothesis is that the fish community composition has been altered in areas containing invasive fish species. Areas with invasive fish species are expected to exhibit decreased numbers and average body size of native fish species when compared to areas lacking invasive fish species.

Methods

Study Area

Two watersheds of Clear Lake, Clear Creek and Armand Bayou, which have reported the sightings of invasive species in recent years (Guillen, pers. comm.), were studied. Eight sampling sites within the Armand Bayou and Clear Creek watersheds were selected and stratified along the natural conductivity gradient and the degree of anthropogenic disturbance (Figure 1). Latitude and longitude for each sampling site are provided in Table 1. Four sample sites were monitored in each watershed. The four sample sites for Armand Bayou were located at Armand

Bayou at Holly Bay, Armand Bayou at Fairmont, Horsepen Bayou at Space Center, and an unnamed tributary of Horsepen Bayou in the Brookforest subdivision at Craighurst. The four samples sites within the Clear Creek watershed were located at Mary's Creek at Independence Park, Coward's Creek at Clover Field, Chigger Creek at Windsong, and Magnolia Creek at FM 518. At each site, the total study area consisted of a 300-foot long section or reach of the stream.

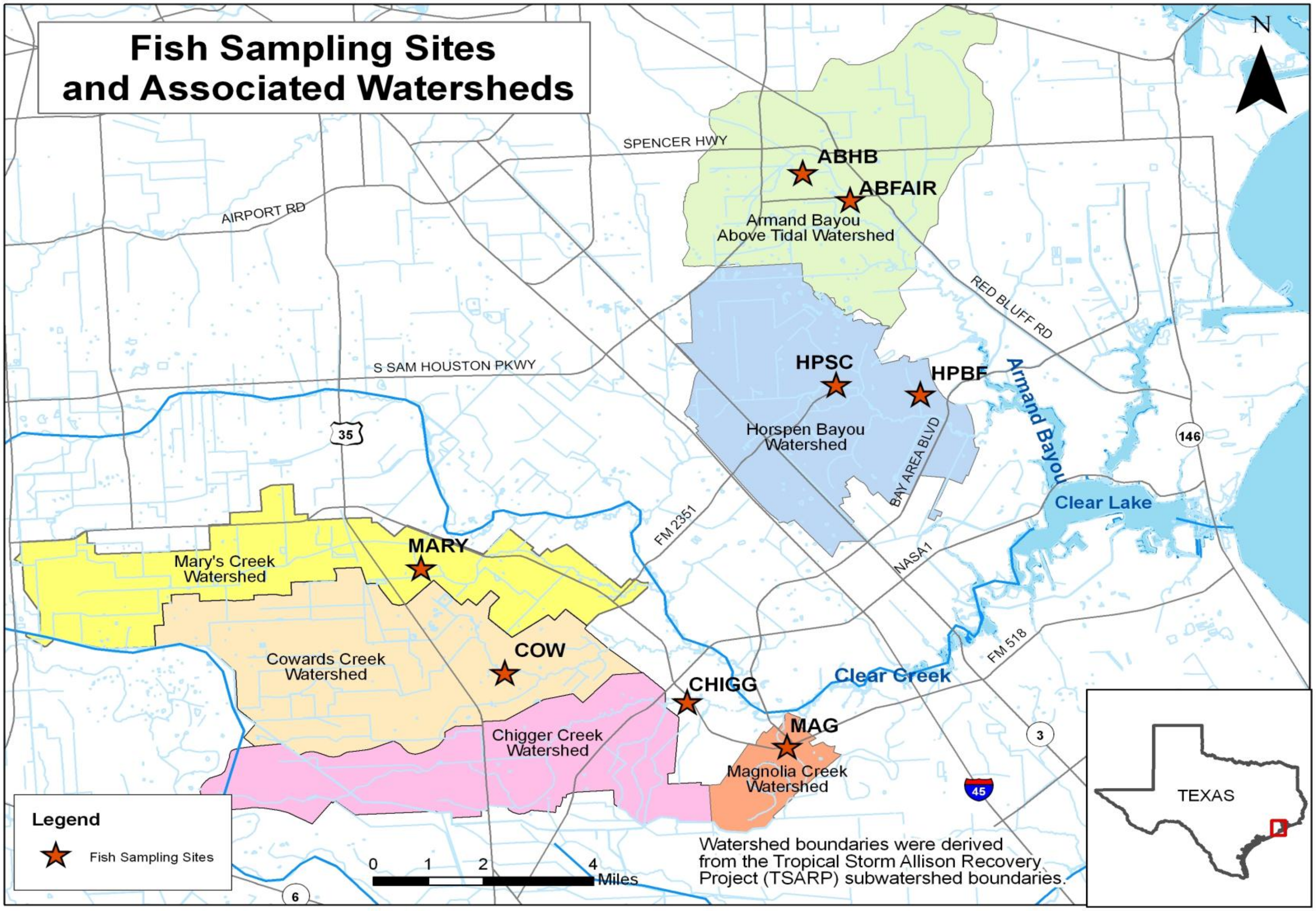

Figure 1: Map showing sampling sites and associated watersheds (created by H. Biggs).

Table 1: Latitude and Longitude of sampling sites

Sampling Site*	Latitude (N)	Longitude (W)
Armand Bayou at Holly Bay (ABHB)	29.70917	-95.3561
Armand Bayou at Fairmont (ABFAIR)	29.90833	-95.3297
Horsepen Bayou at Space Center (HPSC)	29.594167	-95.140833
Unnamed tributary to Horsepen Bayou at Brookforest (HPBF)	29.76556	-95.2594
Mary's Creek at Independence Park (MARY)	29.545278	-95.263333
Coward's Creek at Clover Field (COW)	29.513889	-95.239722
Chigger Creek at Windsong (CHIGG)	29.494722	-95.223333
Magnolia Creek at FM 518 (MAG)	29.48889	-95.155556

* ( ) site name abbreviation used throughout report

Site Selection

Sites were stratified according to conductivity. Conductivity has been shown to influence the distribution and composition of fish communities in coastal areas (Monaco, et al. 1989). Therefore, conductivity is a key variable that must be evaluated in order to interpret observed fish community structure. In general, conductivity and salinity are highest near the mouths of each tributary. Typical highest salinity and conductivity measurements were expected to be 3-6 practical salinity units (psu) and 1,000-2,000 microsiemens (μS), respectively (http://www.hgac.com).

I further classified the sites based on anthropogenic disturbance. For site selection the initial degree of degradation was estimated by the amount of wastewater loading near the station. Data on wastewater loading was obtained from the TCEQ databases found online at that agency's website (http://www.tceq.state.tx.us/). The key variable evaluated was permitted wastewater discharge volumes. Degraded waterways and their associated stations were classified as having higher volumes of wastewater discharge. There were five wastewater treatment plants whose effluent discharged upstream of my sampling sites. Based on data provided by TCEQ, three wastewater treatment plants discharge into Mary's Creek upstream of the sampling site, one wastewater treatment plant discharges into Coward's Creek upstream of the sampling site and the other wastewater treatment plant discharges into Horsepen Bayou upstream of the Horsepen at Space Center sampling site (J. Rice personal comm.). These potentially degraded sites were expected to have an increased amount of invasive fish and a decreased amount of native fish when compared to the less degraded sites.

Land use was also utilized as an indicator of potential degradation. Land use data was obtained from HGAC land use land cover data (2002) and recent TMDL studies in the watershed (TCEQ, 2006). A GIS map was created and land use was determined for each subwatershed (Fig. 2). Horsepen Bayou had the most development within its watershed at 71.1%, Armand Bayou was the next most developed with 56.6% of the watershed developed. Mary's Creek watershed was the third most developed with 53% of its land use designated as developed. Magnolia Creek had the greatest percentage of wetlands within its watershed at 6.4%, whereas Horsepen Bayou had 0% designated as wetlands.

Table 2: Land use percents as determined by GIS analysis of watersheds.

VALUE	Land UseType	Horsepen Bayou	Armand Bayou	Mary's	Coward's	Chigger	Magnolia
1	Low Intensity	38.6%	24.5%	23.5%	17.5%	13.5%	13.5%
2	High Intensity	32.5%	32.1%	29.5%	7.2%	7.8%	13.3%
3	Cultivated	0.0%	0.3%	0.8%	2.9%	7.8%	3.6%
4	Grassland	25.3%	29.6%	29.8%	47.2%	38.2%	46.6%
5	Woody Land	1.2%	9.5%	11.6%	20.8%	29.0%	13.6%
6	Open Water	0.0%	0.8%	1.4%	0.6%	1.1%	0.9%
7	Woody Wetland	0.0%	0.6%	0.4%	0.5%	1.1%	1.1%
8	Non-Woody Wetland	0.0%	1.5%	1.5%	2.9%	0.7%	5.3%
9	Bare/Transitional	2.4%	1.1%	1.5%	0.4%	0.8%	2.1%

*Land use based on HGAC LULC Classifications

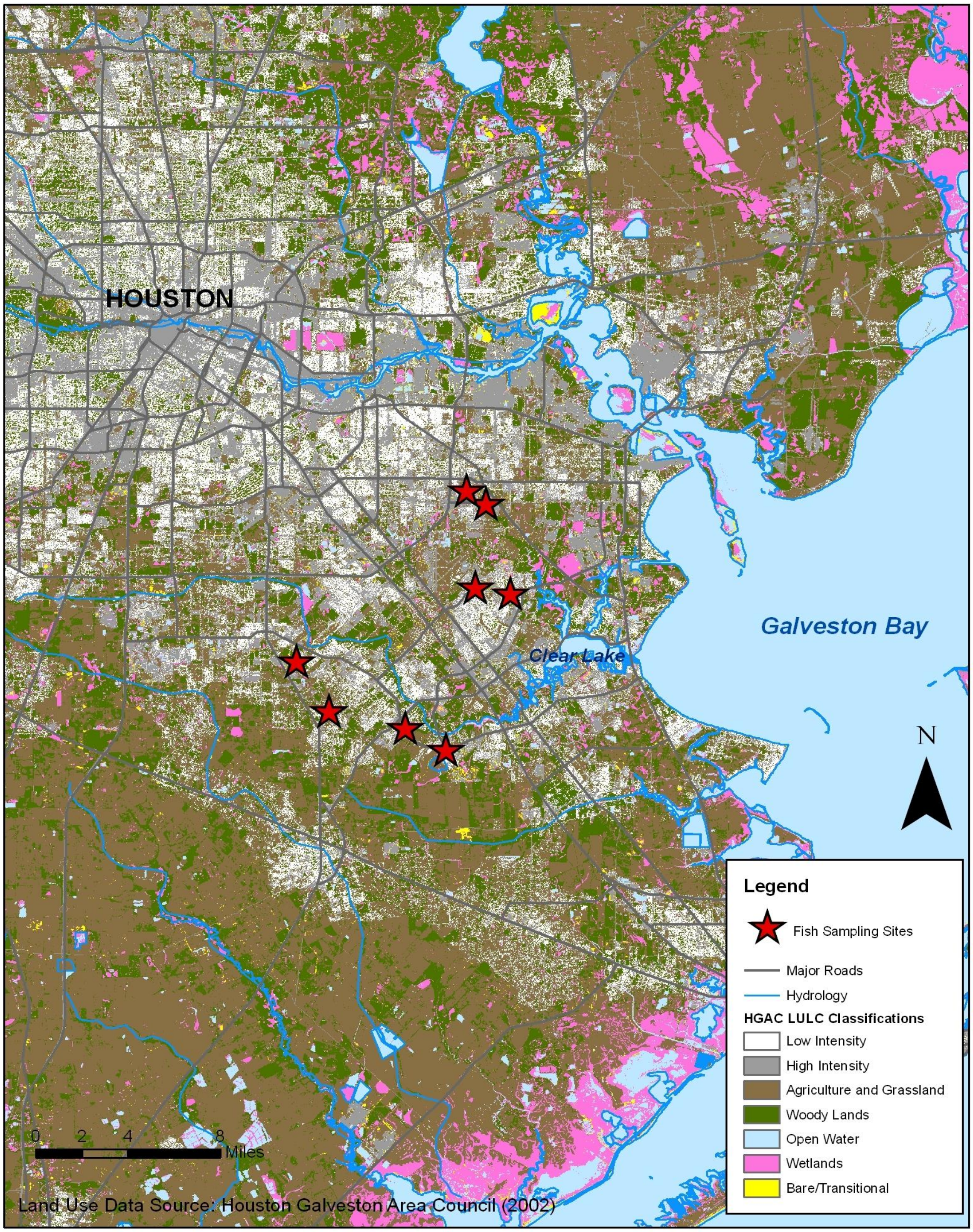

Figure 2: Land use for sampling area, data from HGAC LULC 2002 (created by Heather Biggs).

Sampling Period

The likelihood of finding invasive fish species is increased during the summer months when water temperatures are higher (Martin, 2000). Therefore, sampling at each site was conducted on a monthly basis from June to September, with one sample conducted in October, for a total of four monthly periods per site.

Field Sampling Procedures

A Smith-Root model LR-24 backpack electrofisher using the standard operational parameters of 30 Hz pulsed D.C. electrical current, with a frequency of 105 volts was used to obtain fish from each sample station. All settings including the voltage, watts, type of wave, and amps, from the electrofisher were recorded in a field notebook prior to sampling. Based on current literature and manufacturers recommendations, at conductivities exceeding 1000 µS electrofishing is ineffective; therefore in these circumstances only seining was used to collect fish (Pusey et al, 1998 & Hill & Willis, 1994).

At each 300 ft sampling site, three 100 ft long, non-overlapping replicate electrofishing collections were conducted to collect specimens not susceptible to seining. The exact time shocked during each collection was recorded in the project field notebook. Shocking started at the downstream end and moved upstream. While one person ran the backpack shocker, another person collected stunned fish with a dip-net and placed them in a collection bucket. After completion of the electrofishing survey, we waited a period of thirty minutes before seining. In summary, we attempted to collect a minimum of (10 sites X 4 months X 3 collections/site) 120 electroshocking samples during the duration of the study.

Ten non-overlapping replicate 30 ft seine collections were conducted within the 300 ft sample site to collect any specimens which were not susceptible to electrofishing efforts. The seine that was used is a 15 ft by 4 ft common sense seine, with a 1/8 inch delta weave mesh. Seine sampling started upstream and was conducted moving downstream. Each seine haul was treated as a separate collection. In summary, we attempted to collect a minimum of (10 sites X 4 months X 10 collections/sites) 400 seine samples.

MS-222, a euthanizing agent, was used to sacrifice each fish. All fish collected with electrofishing or seining were placed in a bucket containing the MS-222 solution prior to preservation. All fish collected were preserved by placing them in a plastic bag containing a 6-7% solution of formalin. Each bag was labeled with the location, site, collection number, and date. The bag was then placed inside a bucket for transport to the University of Houston Clear Lake laboratory for analysis. At the laboratory fish collections were transferred to 40% isopropanol or 70% ethanol for long-term storage prior to identification.

To characterize each tributary, physical, hydrological and water quality variables were measured at each sample site. The variables that were measured have been shown to influence the composition and distribution of fish in stream ecosystems (Harrelson et al. 1994; Bain and Stevenson 1999; Gordon et al. 1992). It is necessary to measure these variables to determine if changes in native fish communities and presence of invasive species may be due to habitat differences associated with stream degradation.

The physical characteristics at each site were determined through measurements of stream and riparian morphology. Each physical habitat variable was measured according to the following protocol. At each 30 ft seining location interval, the stream morphology was classified as pool, riffle, or run. This was subsequently used to determine the habitat complexity, which is the standard deviation of the mean scores of pools, riffles, and runs (pool = 0, run = 1, riffle = 2) per site. Three perpendicular transects to the streambed axis were also established at the upper, lower and middle portion of each sample site. Depth measurements were collected from the thalweg, or center portion of the deepest channel, at each transect. Total stream width from wetted edge to wetted edge was measured at each transect. The percent stream bottom covered by 1) submerged vegetation, 2) emergent vegetation, 3) concrete/boulders and 4) soft sediment was visually estimated at each transect. In addition, at each transect three measurements, right bank, midstream and left bank, were taken of sediment using a modified Wentworth scale. The stream bank slope was also measured on both banks, at each transect, using a pocket clinometer (Bain & Stevenson, 1999). These various in stream habitat variables are highly correlated with stream fish community structure and are often altered in degraded systems. For example, due to urban development within the watershed, degraded stream systems often exhibit increased incised banks, channelization, and resulting steep erosion prone banks and increased siltation (Bryan & Rutherford, 1993).

Each sampling site was surveyed using the methods outlined in Bain and Stevenson (1991) to characterize and determine differences in the basic longitudinal and cross-section profile between sites. Water surface elevation was also measured. Chigger Creek had two distinct bank areas, therefore two separate transects were conducted. Stream cross-sections and slope were measured using a Sokkia Total Station and laser level. Stream sinuosity was measured for any sites that were not channelized. Sinuosity was determined by the ratio of stream channel length to straight line length. These data were used to help determine whether sites were physically similar and if they showed signs of habitat degradation such as steep eroding shorelines.

Hydrological characteristics that were measured included mid-channel velocity and stream flow. The mid-stream velocity in feet per second (fps) at each transect previously discussed was determined at the thalweg of the stream using a wading staff and a pygmy price current meter. TCEQ (2003) and American Fisheries Society (Gallagher & Stevenson, 1999) standard protocols were used to determine the depth that the stream velocity was measured. If the stream was <2.5 feet deep, the measurement was taken at 0.60 times the total depth. If the stream was >2.5 feet deep, then the measurement was taken at 0.20 and 0.80 times the total depth. A standard ten point transect was used for flow calculation was conducted as described in TCEQ (2003) and Gallagher & Stevenson (1999). Stream flow in cubic feet per second (cfs) was measured at the upper end of each site by dividing the width of the stream into ten equal width survey cells. Velocity within each survey cell was measured using the protocol previously described for velocity measurements. Flow within each cell was calculated by multiplying velocity times cell width and height. Total stream flow in cubic feet per second (cfs) was calculated by summing individual cell flows. Stream flow and velocity are highly correlated with stream fish community structure and are often altered in degraded systems. For example, degraded stream systems often exhibit altered flow regimes and higher velocities due to channelization and loss of instream cover (Bryan & Rutherford, 1993).

Water quality was also characterized at each sample site. Abiotic factors including, temperature, pH, salinity, alkalinity and specific conductance were measured at a transect located at the upper end of each station. Dissolved oxygen and water clarity (secchi tube (cm) and ntu) were measured at transects located at the upper, middle and lower end of each site. These measurements were taken using test kits or meters following manufactures' instructions (Table 2). In addition, ammonia, nitrate-N and orthophosphates were measured using HACH test kits. Meters and test kits were calibrated within 24 hours of sampling using standard test solutions of known concentration. Manufacturer's directions were followed for all water quality parameter testing. The water quality variables that were measured have been shown to influence stream fish community structure and are often altered in degraded systems. For example, degraded stream systems often exhibit increased water temperatures, elevated nutrients, and wider diel variations in dissolved oxygen associated with increased wastewater loading and eutrophication (Bryan & Rutherford, 1993).

Table 3: Water quality variables monitored and sampling method

Water Quality Parameter (units)	**Type of kit or meter**
Dissolved Oxygen (mg/L)	LaMotte Test kit Model EDO code 7414
pH	Oakton Instruments: pH Testr 2
Conductivity (µS)	Oakton Instruments: EC Testr
Temperature (°C)	Thermometer
Orthophosphate (mg/L PO_4)	Phosphorus, reactive Method 8048 using a Hach DR/890 Colorimeter (filtered with 47mm filter paper) (detection limit 2.50 mg/L)
Nitrate (mg/L NO_3-N)	Nitrate, low-range Method 8192 using a Hach DR/890 Colorimeter (detection limit 0.50 mg/L)
Alkalinity (mg/L $CaCO_3$)	LaMotte Kit Model WAT-DR code 49-DR
Ammonia (mg/L NH4)	Hach Kit Midrange Model NI-8 (detection limit 3 mg/L)
Salinity (psu)	Hydrometer
Turbidity (cm & ntu)	Secchi Tube and Scientific Inc. Turbidimeter

Data Analysis

All fish were identified to the lowest taxonomic level possible. In most cases specimens were identified to species level to facilitate comparisons between individual species abundances and the presence of invasive species. This identification was also used for further calculation of number of fish species and fish diversity indices. The identified fish were counted to determine the total number of each species, as well as the total number of fish collected in the study. Regional taxonomic guides and keys were used to aid in identification.

The standard length (mm) of a subsample of each native species, not to exceed ten fish per species, was measured. The total length and standard length (mm) for all invasive fish were measured. This allowed the investigator to compare the relative age and size structure of native and invasive fish species. Fish communities that have been negatively affected by an efficient predator or superior competitor, including invasive species, will often exhibit stunted growth or loss of older cohorts (Traxler & Murphy, 1995 & TCAFS, 2005). Computations of the number of species, number and abundance of native fish species, average size of native fish species, number and abundance of sunfish species, number and abundance of invasive species, number and abundance of cichlids (includes both Tilapia and Rio Grande cichlids), and community diversity indices were conducted for use in later calculations. Diversity indices were standard indices modified to describe fish communities. The indices used were Shannon-Wiener's Diversity (H\`), Pielou's evenness (E), and Richness (Krebs, 1998). These computed indices were used to determine if there was a decline in the abundance, size and diversity of native fish due to the presence of invasive fish species.

Each seine and electrofishing collection made at each station was treated as a replicate measurement for purposes of statistical analyses. In addition, each physical habitat, water quality and fish length measurement made at each station was treated as a replicate observation. Electroshocking catches were converted to catch per unit effort (CPUE) using units of number of fish collected per minute. All analyses of electrofishing data were conducted on CPUE.

Multiple statistical methods were used to analyze the data collected during sampling. A cross correlation analysis and associated scatter plots were used to evaluate the relationship of the following variables: 1) average invasive species abundance; 2) average native species abundance; 3) average sunfish (Family Centrachidae) abundance; 4) average size of native fish 5) average number of Rio Grande Cichlids; 6) average Shannon's Diversity (H'); 7) average Evenness (E); 8) water temperature; 9)average dissolved oxygen; 10) conductivity; 11) nutrient levels; 12) average percent bottom composed of emergent plants; 13)average percent bottom composed of submerged plants; 14) average sediment size (from Wentworth score); 15) average water clarity (from secci tube); 16) stream flow and 17) average mid-stream velocity. This was done to determine which variables exhibit the strongest relationship with the distribution of native and invasive fish.

Only variables that appear to be highly correlated with native and invasive fish were selected for further statistical analysis. These variables were selected after examining the cross-correlation matrix and scatter plots for those variables. Candidate variables included water temperature, dissolved oxygen, conductivity, pH, nutrients, velocity, and submerged vegetation and substrate type. To further test the hypothesis that invasive species are affected by habitat and water quality characteristics a stepwise multiple regression analysis was conducted to determine which factors have the most potential influence on the number of invasive species present (Ryan et al. 2005).

Graphical box-plots for each variable measured during the study were produced for each site by month combination to further facilitate spatial temporal analysis. A two-way analysis of variance, which incorporates two factors, sites and months, using the General Linear Model was conducted. If significant differences were found between sites and months for any variable at the $p<0.05$ level, a Tukey's multiple comparison test was used to determine which collection was significantly different for a particular variable. This analysis was done to determine if sites previously described as being degraded based on the a priori criteria do in fact contain any of the following characteristics including higher numbers of invasive species, reduced native species abundance, stunted growth, and poor water quality.

Cluster analysis of the species community data was conducted to determine the similarity of sites and months in terms of overall community composition. Squared Euclidean Distance and Ward's Linkage method were used for cluster determination. In addition, Clustan was used to determine the final number of group clusters. Clustan uses a variance reduction algorithm and then replicates the best cut to determine how many clusters are significant, therefore determining where the classification tree should be cut (Wishhart, 2006). Sites with invasive species were expected to differ significantly in community composition from sites lacking invasive species. They would exhibit higher similarity with other sites possessing invasive species. Stepwise discriminate analysis using SPSS was conducted using the cluster designations as grouping variables to determine which variables affected this designation (SPSS Inc., 1991).

A principal components analysis (PCA) was used to determine how the environmental and biological components of the study were interrelated. PCA is an ordination technique that reduces numerous variables into explanatory principal components that can be used to predict interrelationships between variables and observations (Tabachnick & Fidell, 1989). PC ORD, using a correlation matrix, was used to conduct the PCA (McCune & Mefford, 1999). Initial variables used to conduct PCA included dissolved oxygen, pool percent, run percent, riffle percent, habitat complexity, water clarity, stream width, thalweg depth, phosphate, nitrate, conductivity, temperature, ammonia, sediment size, overall fish abundance, fish community diversity, fish community evenness, fish community richness, centrarchid abundance, cichlid abundance, percent submerged vegetation, percent emergent vegetation, stream velocity, and pH.

RESULTS

During this study we collected physical, hydrological, water quality and biological data from 8 sites, over a four month period extending from June to October 2006. Additional supplementary data on the occurrence of invasive species was also collected at Armand Bayou at Bay Area Park. Due to data gaps this site was not included in our statistical analysis. Detailed tabulations of raw data including results of statistical analyzes are presented in the accompanying appendices (Appendices I-XII).

Physical Site Characterization:

Stream cross-sectional profiles were generated from transects conducted at each sampling site. The profiles are presented for the Clear Creek watershed and the Armand Bayou watershed in Figure 3. Chigger Creek has two profiles due to the fact that two distinct stream bank areas were present. All of the sampling sites except for Magnolia Creek were channelized, showing little to no sinuosity. Magnolia Creek exhibited a more natural stream channel and was more naturally sinuous with a sinuosity of 1.271. This level of sinuosity is considered to be moderate (Bain & Stevenson, 1999).

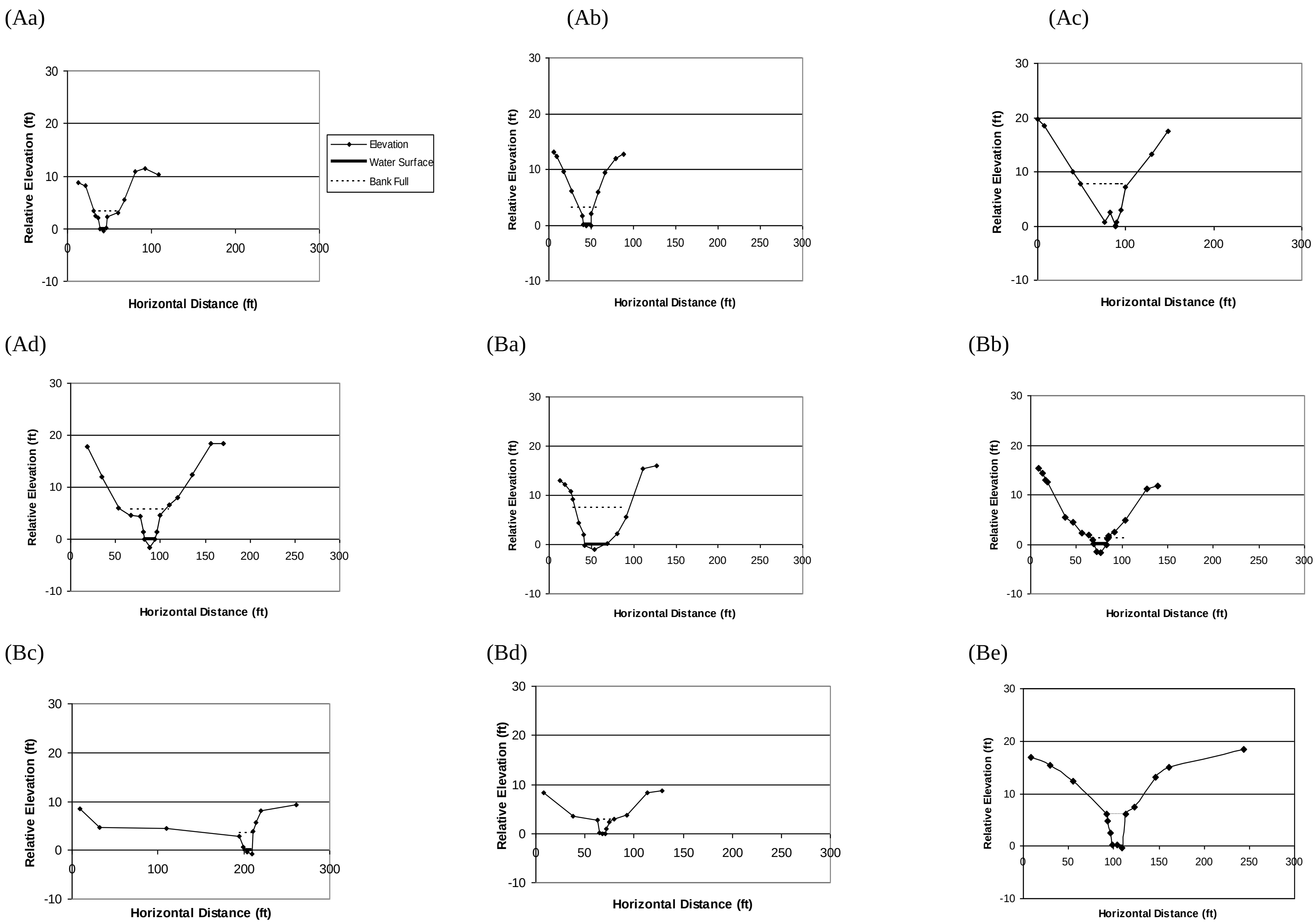

Figure 3: (A) Armand Bayou watershed stream profiles (a) Armand Bayou at Holly Bay (b) Armand Bayou at Fairmont (c) Horsepen Bayou at Brookforest (d) Horsepen Bayou at Space Center and (B) Clear Creek watershed stream profiles (a) Mary's Creek (b) Coward's Creek (c & d) Chigger Creek (e) Magnolia Creek using the horizontal distance (ft) as measured with a total station and the relative elevation (ft) at each point measured sampling site.

The average stream width was significantly different (p=0.00, R^2= 88.77) amongst sites. Figure 4 illustrates the stream width (ft) per site, sites with the same letter are not significantly different. There was also a significant interaction between sites and months (p=0.006). The mean stream width at the site MARY was greater than twice the recorded mean width at all other sites. The sites ABFAIR and MAG had the least amount of variation in stream width. Within the sites sampled in the Clear Creek watershed stream width decreased from upstream to downstream.

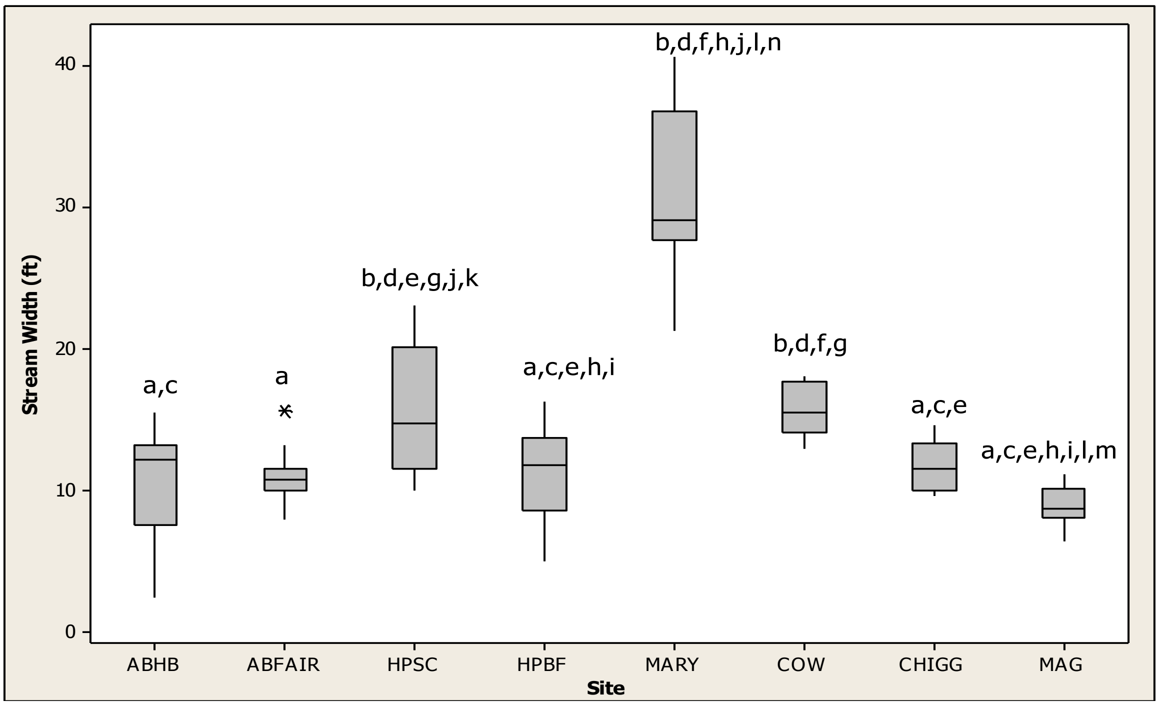

Figure 4: Stream width (ft) upstream, midstream, and downstream combined per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values, * represents outliers. Letters represent sites which are significantly different based on results of ANOVA (p=0.000, R^2=88.77) with Tukeys multiple comparison pairwise family test (alpha level =0.05).

The thalweg depth was significantly different between sites (p=0.000, R^2=78.02) and between months (p=0.005)(Figure 5). A Significant interaction between sites and months did occur (p=0.000) as well. ABFAIR and HPBF had the shallowest thalweg depths, while COW had the deepest depth. The least variation in thalweg depth occurred at HPBF and ABFAIR as well.

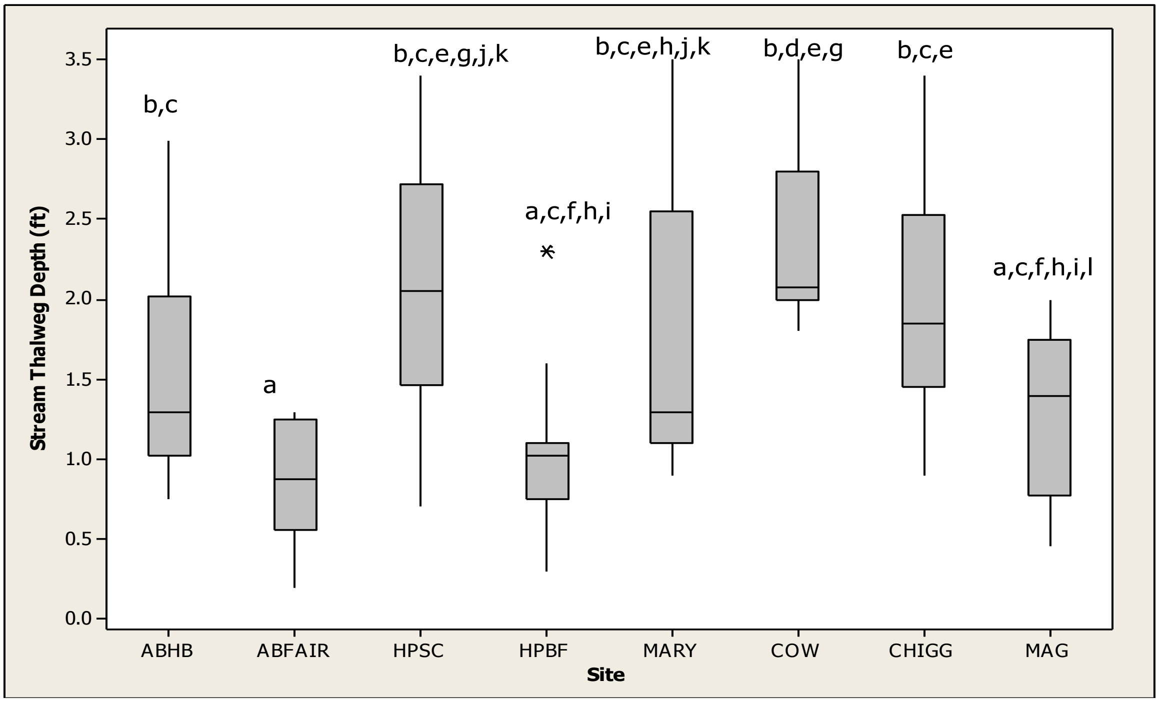

Figure 5: Thalweg depth (ft) upstream, midstream, and downstream combined per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values * represent outliers. Letters represent which are significantly different based on results of ANOVA (p=0.000, R2= 78.02) with Tukeys multiple comparison pairwise family test (alpha level =0.05).

In order to show what the habitat within each stream was, the percent riffle, percent run, and percent pool were calculated and graphed. The percent of the stream that was a pool is illustrated in Figure 6. The site ABHB had the highest mean percent pool. MARY and COW had no pools as mentioned above. All other sites had means between 20–35% for percent pool.

The sites HPSC, MARY and COW all had no riffles within the sampling area (Figure 7). HPBF, CHIGG and MAG had very low mean percent riffles, with less than 10% of the stream segment being riffles, although the site CHIGG did have the most variation in riffle percent throughout the study.

The sites MARY and COW had 100% runs throughout the study area. ABFAIR and ABHB had the lowest mean percent runs. CHIGG continued to have the most variation in stream habitat (Figure 8).

Habitat complexity, which was represented by the distribution of pool, riffle, run complexes within the stream, was unable to be analyzed with an ANOVA due to small sample size (Figure 9). The greater the habitat complexity value the greater the variation of pools, riffles and runs. COW and MARY sites both had 0 values for the habitat complexity, meaning that those sampling sites exhibited no variation in stream morphology. Both of these sites were channelized and only had runs throughout our sampling segment as seen in Figure 8. ABHB and ABFAIR had the most variation in habitat, with high habitat complexity scores. The habitat complexity scores varied the most at the site HPSC throughout the sampling period.

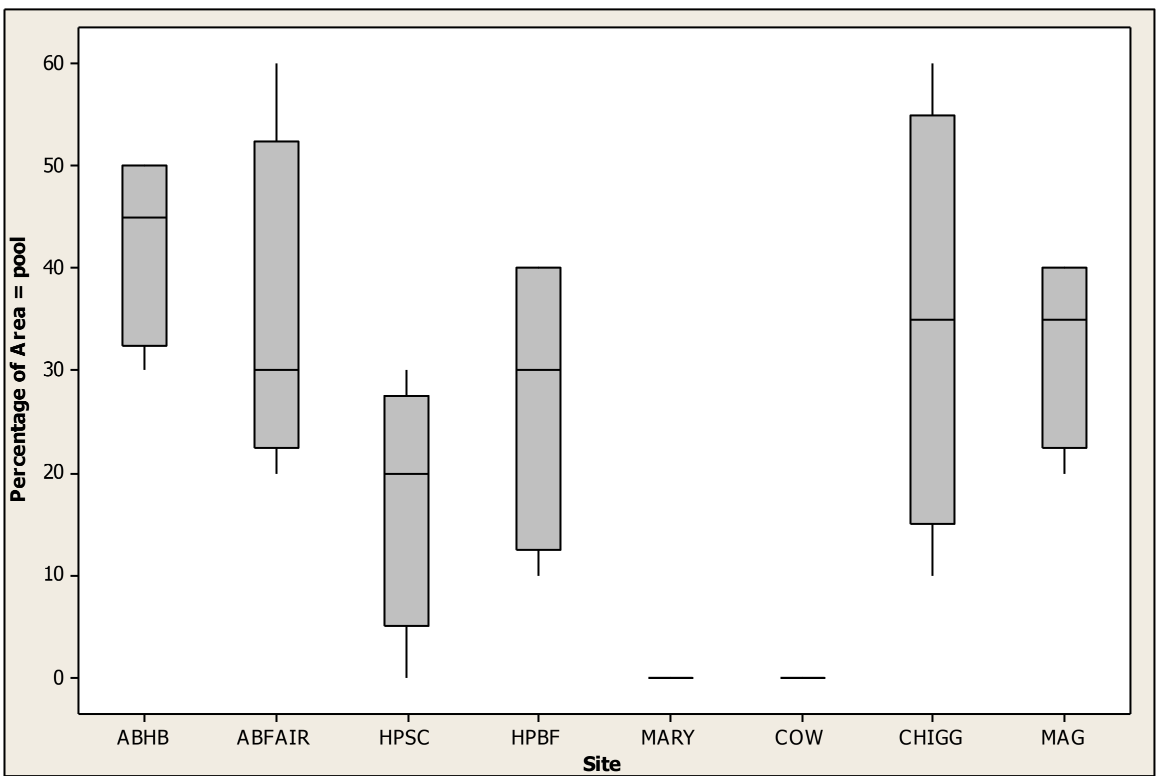

Figure 6: Percentage of sample area that was a pool. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values.

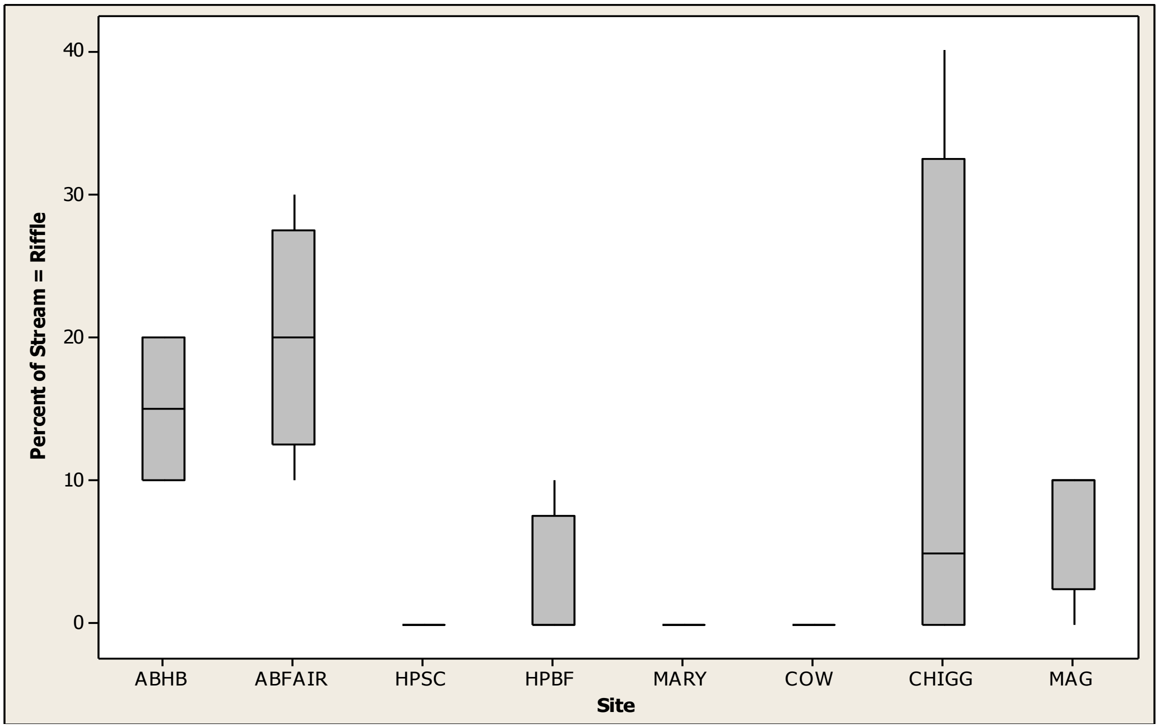

Figure 7: Percent of Stream that was a riffle area. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values.

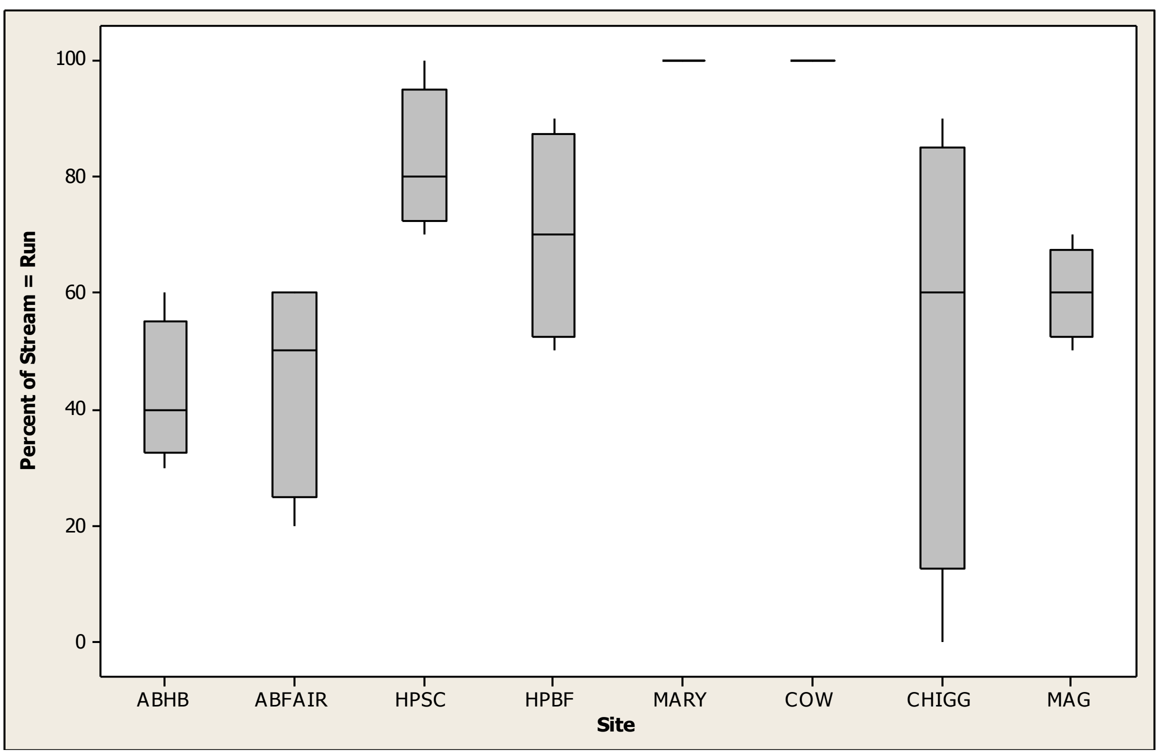

Figure 8: Percent of stream that was a run. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values.

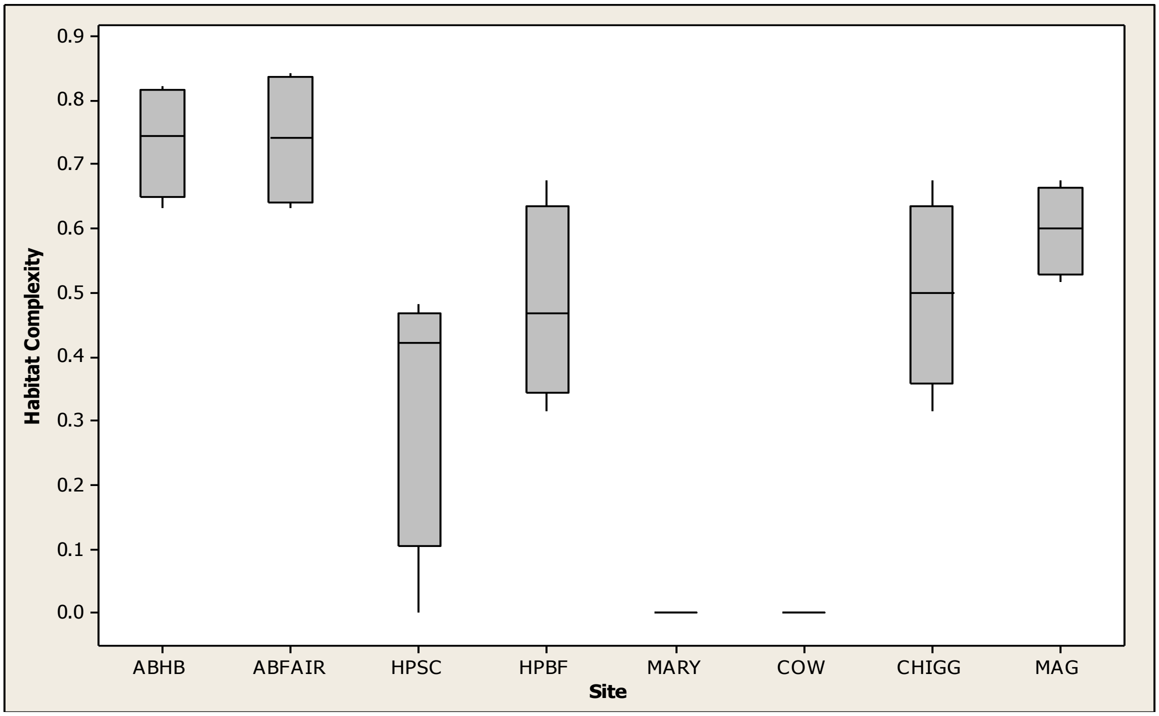

Figure 9: Habitat complexity per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values.

Summary data for bank slope is provided in Figure 10. The greater the angle of the bank slope the steeper the bank. Bank slope also was significantly different between sites (p= 0.00 R^2= 72.28). ABFAIR, HPBF and MAG had the steepest mean bank slope at over 80 degrees. The sites with the lowest slope degrees were MARY and COW. All sites except ABFAIR had lots of variation in stream slope, with some sites ranging from 0° to 90°.

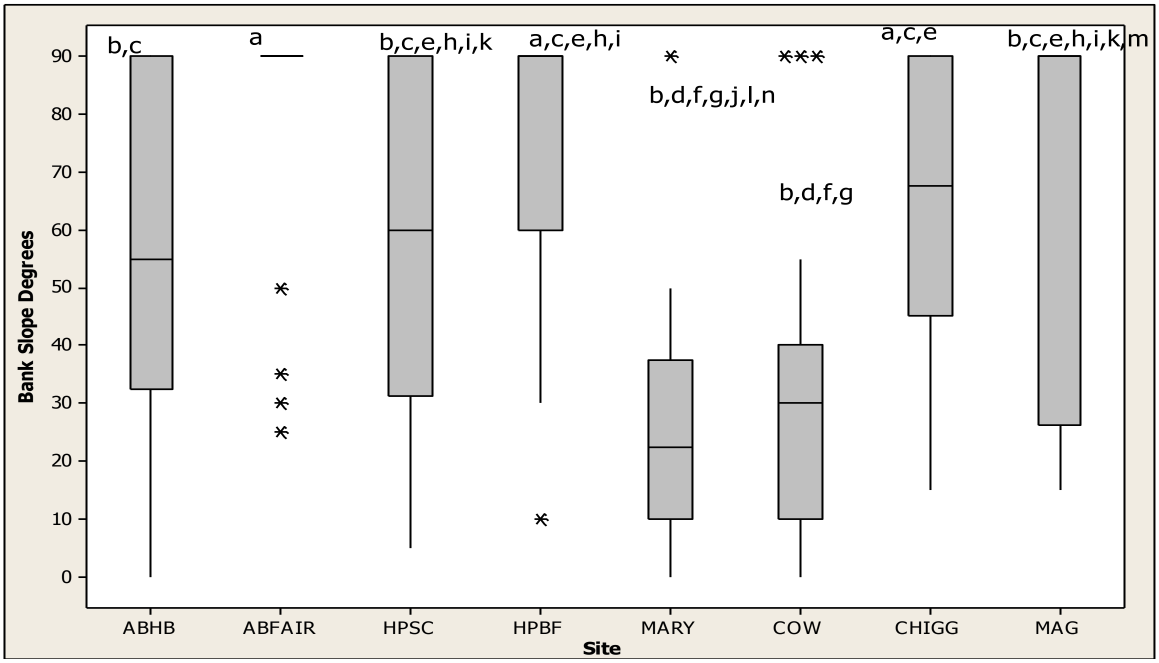

Figure 10: Bank slope degree per site for upstream, midstream, and downstream combined. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values, * represents outliers. Letters represent groups which are significantly different based on results of ANOVA (p=0.000, R^2= 44.08) with Tukeys multiple comparison pairwise family test (alpha level = 0.05).

There was significant difference found between sites for submerged vegetation and emergent vegetation, p=0.000, R2 = 77.01 and p=0.021, R2 = 43.53, respectively (Figures 11 and 12). A significant interaction did occur between sites and months (p=0.000) for the submerged vegetation. ABHB, ABFAIR and COW had means of 0 for percent submerged vegetation. MARY and CHIGG had very low, less than 20%, amounts of submerged vegetation, all sites had means less than 50%. MAG had the highest mean percent submerged vegetation. The ANOVA with Tukeys multiple comparisons pairwise family test (alpha level 0.05) was unable to determine which site was significantly different for the emergent vegetation. ABHB, HPBF, MARY, COW, CHIGG, and ABFAIR all had 10% or less emergent vegetation.

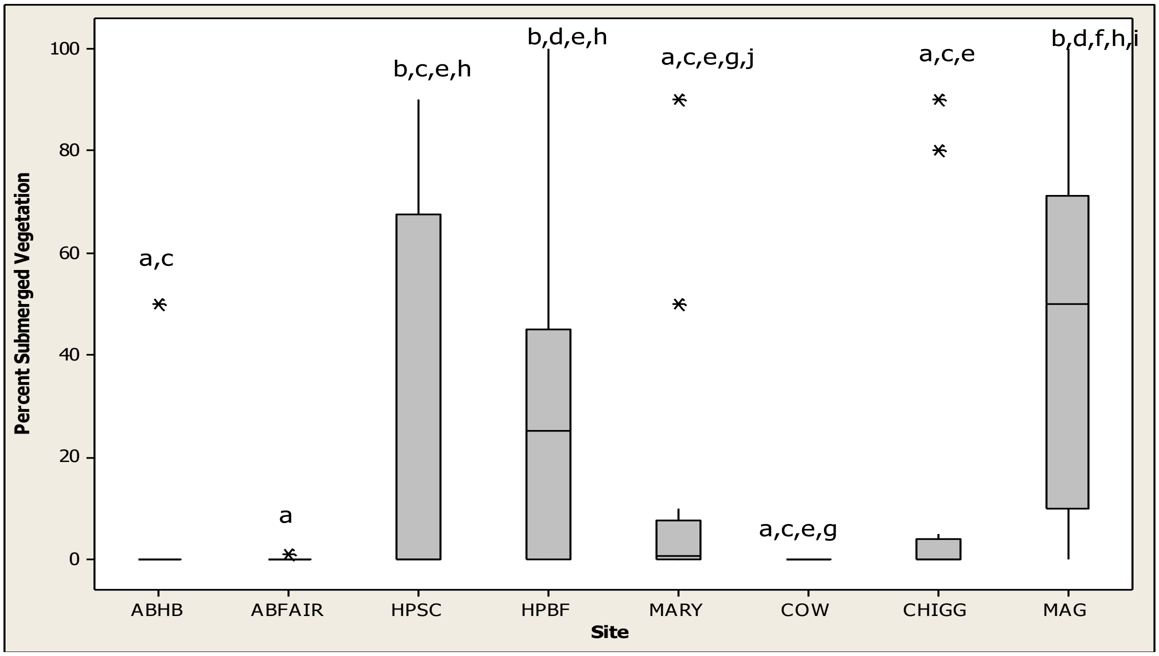

Figure 11: Percent submerged vegetation for upstream, midstream, and downstream transects combined. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values, * represents outliers. Letters represent sites which are significantly different based on results of ANOVA (p=0.000 R^2=77.01) with Tukeys multiple comparison pair wise family test (alpha level = 0.05).

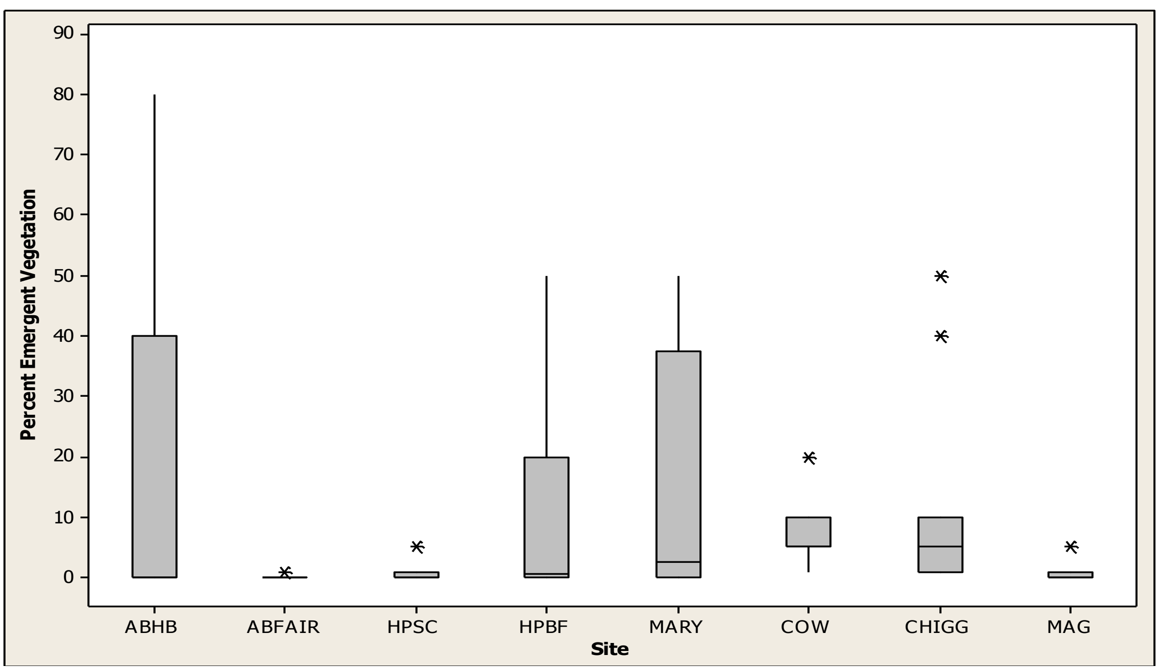

Figure 12: Percent emergent vegetation for upstream, midstream, and downstream transects combined. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values, * represents outliers. Results of ANOVA (p=0.021, R^2=43.53) with Tukeys multiple comparison pairwise family test (alpha level = 0.05) was unable to determine which site was different.

COW and MARY sites exhibited Wentworth scores of zero for all three transects combined (Figure 13). This indicates that their sediment was composed entirely of clay or silt. In addition, all sites except ABFAIR had mean Wentworth scores of zero, although ABHB and MAG had more variation than the other sites. The site ABFAIR had the highest mean score of 1.5 on the Wentworth scale for the bottom substrate. This score indicated the substrate was composed of pebbles. These differences in sediment size were statistically significant based on results of ANOVA (p=0.000 R^2= 28.64) with Tukeys multiple comparison pairwise family test (alpha level= 0.05). Appendix II summarizes the physical characteristics measured at each site per month.

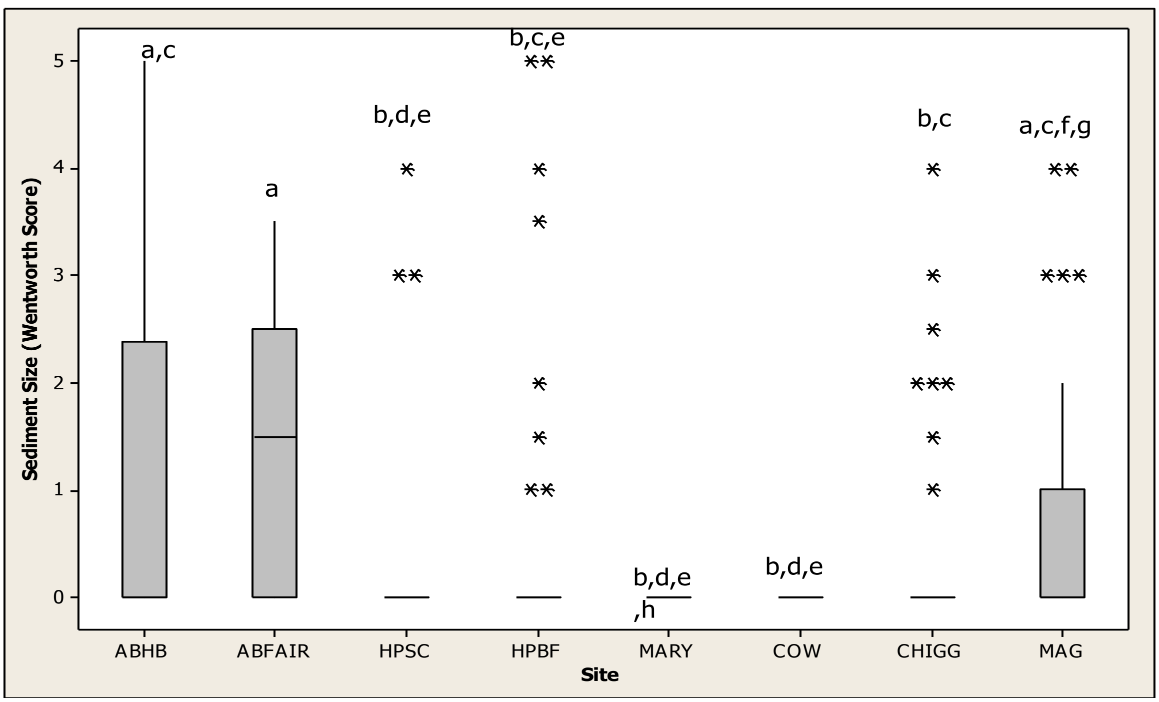

Figure 13: Sediment size based on Wentworth score for upstream, midstream, and downstream transects combined per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values, * represents outliers. Letters represent groups which are significantly different based on results of ANOVA (p=0.000 R^2= 28.64) with Tukeys multiple comparison pairwise family test (alpha level= 0.05).

Hydrology

The hydrology at each site did vary throughout the study. Due to missing values, from instrument failure, an ANOVA was unable to be conducted on the thalweg velocities. Figure 14 illustrates the thalweg velocities per site. HPBF had no measurable velocity throughout the study with one exception. ABHB, ABFAIR, COW and CHIGG all had mean velocities of 0 ft/s. The site MAG had the highest mean velocity throughout the study. COW had the most variation in velocities throughout the study. The flows at each site were also not able to be analyzed using an ANOVA due to small sample size (Appendix II).

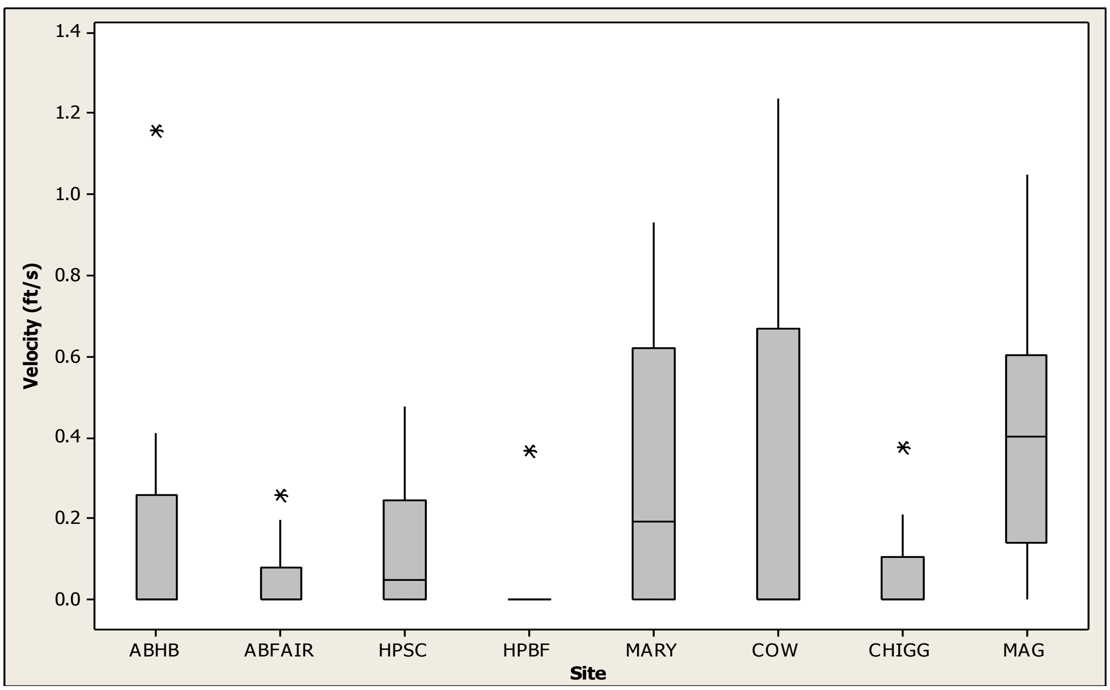

Figure 14: Thalweg velocities (ft/sec) per site. Boxplots of interquartile range with median line. Whiskers represent highest and lowest data values, * represents outliers.

Water Quality

Discussed below are the measured water quality variables at each site. The parameters that differed from site to site were then used for further statistical analyses. Appendix B summarizes the water quality measurements for each site per month.

The site HPSC had the highest mean phosphate levels and the most variation in phosphate levels during the sampling period (Figure 15). MARY had the next highest mean levels of phosphate. ABHB had the lowest mean levels of phosphate during the sampling period. ABFAIR had the least variation in phosphate levels. An ANOVA was unable to be conducted on phosphate due to small sample size.

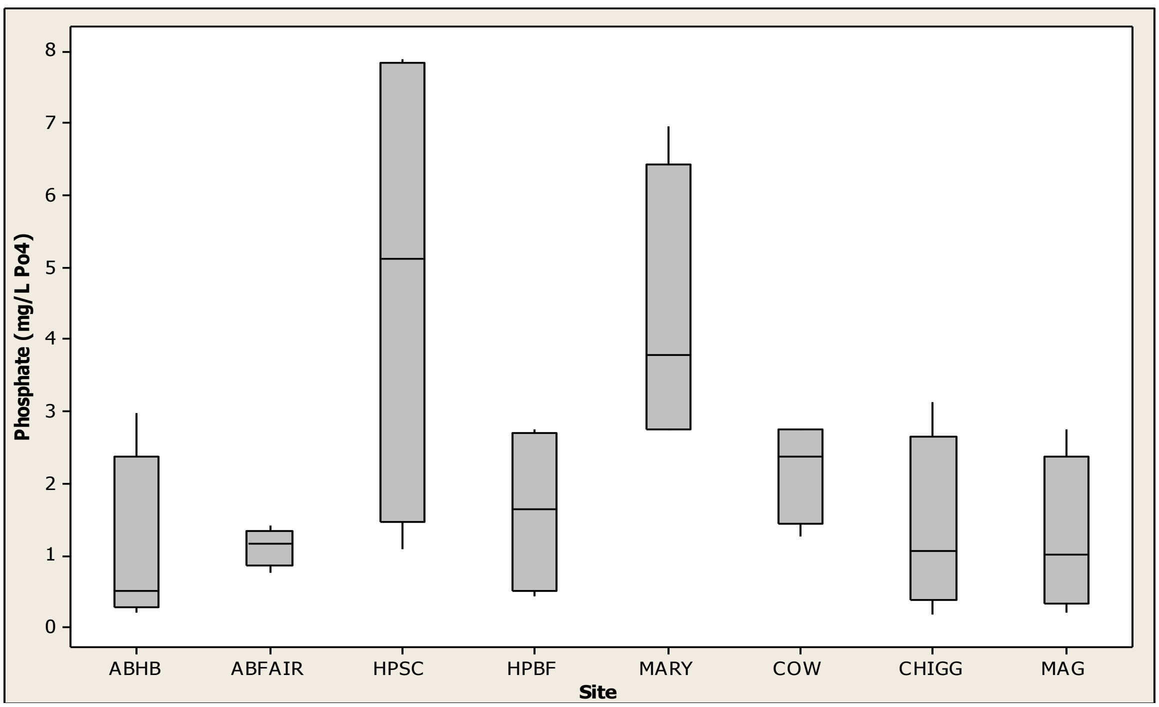

Figure 15: Boxplot of Phosphate (mg/L PO4) per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values within upper and lower limits, respectively.

Alkalinity (mg/L CaCO3) is illustrated in Figure 16. HPBF had the highest mean alkalinity levels, with MARY having the next highest mean levels. ABFAIR had the lowest mean alkalinity levels during the study period. All alkalinity levels are within normal ranges for aquatic life. An ANOVA for alkalinity was unable to be conducted due to small sample size.

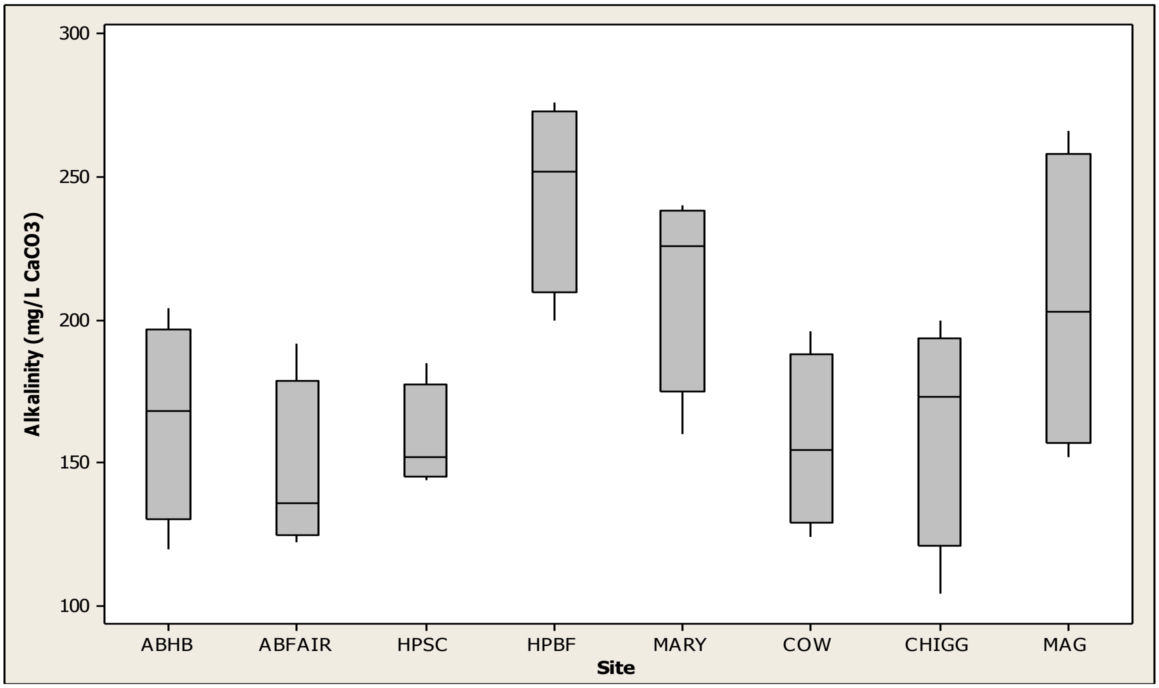

Figure 16: Boxplot of Alkalintiy (mg/l CaCO3) per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values within upper and lower limits, respectively.

Dissolved oxygen (mg/L) levels for all three transects combined per site are illustrated in Figure 17. There was a significant difference between sites (p=0.000), as well as between months (p=0.005). A significant interaction between sites and months (p=0.000) does occur. The highest mean dissolved oxygen levels occurred at MARY, all other sites had mean dissolved oxygen levels below 6.0 mg/L. HPBF, COW, and CHIGG had the lowest levels, all under 4 mg/, of these CHIGG had the lowest mean dissolved oxygen level. The dissolved oxygen levels at HPSC varied the least during the sampling period.

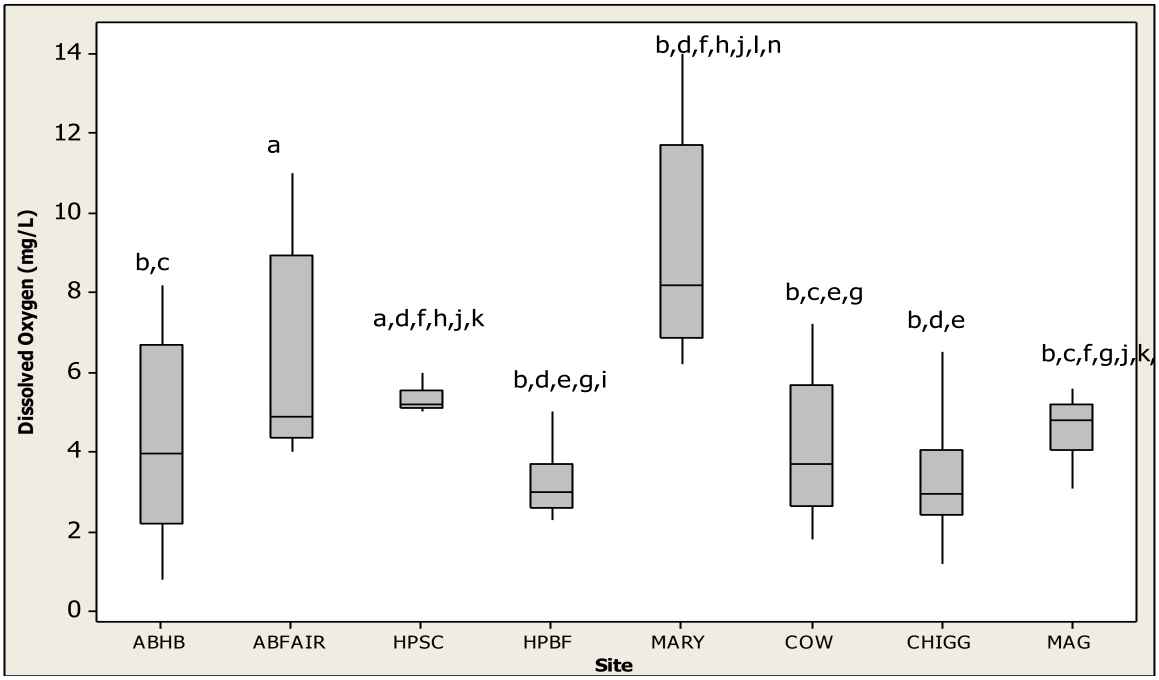

Figure 17: Dissolved Oxygen (mg/L) for all transects combined per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values within upper and lower limits, respectively. Letters represent groups which are significantly different from ANOVA (p=0.000, R^2=94.31) with Tukeys multiple comparison pairwise family test (alpha level= 0.05).

The pH levels at MARY were the highest with all measurements over 8.0 and a mean >8.5 (Figure 18). ABFAIR had the next highest ph levels, over 7.5, whereas all other sites were less than or equal to 7.5. ABHB had the lowest mean pH level. ABHB, HPSC, and HPBF all had little variation in pH levels throughout the study. An ANOVA was unable to be conducted on pH due to small sample size.

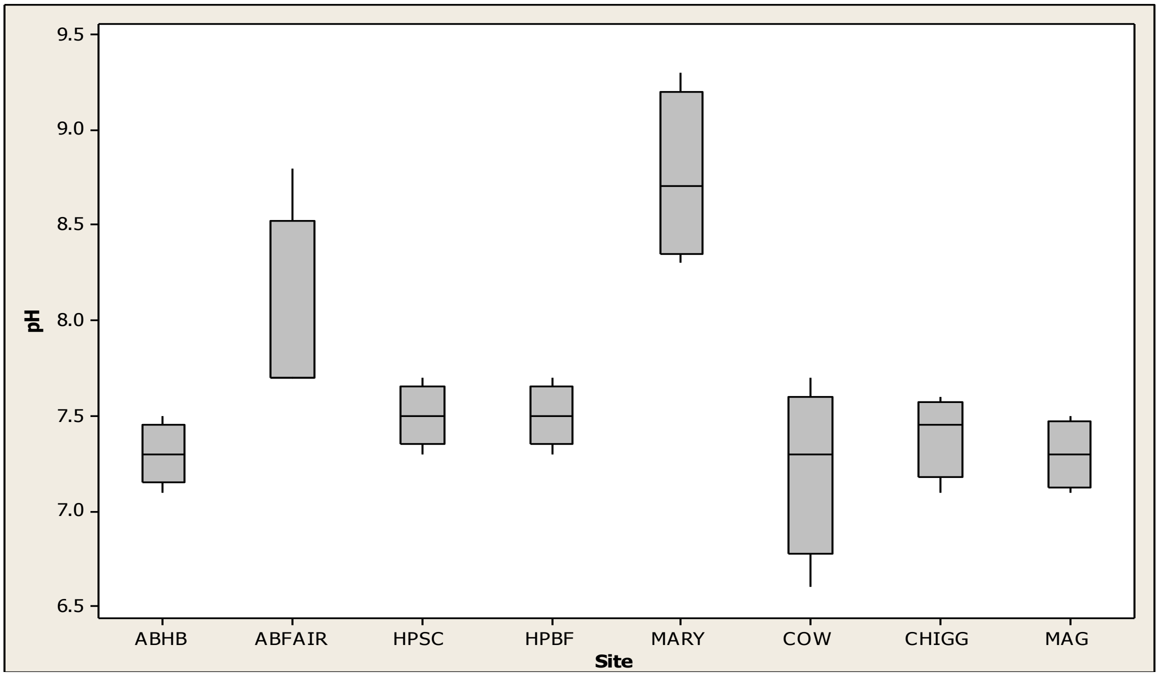

Figure 18: pH per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values within upper and lower limits, respectively.

Water clarity as measured from a secchi tube (cm) from all three transects combined is illustrated in Figure 19. HPBF had the highest water clarity. MARY had the least water clarity, i.e. the most turbid, with the lowest mean secchi measurements. MARY and ABFAIR exhibited the least variation in secchi measurements throughout the study.

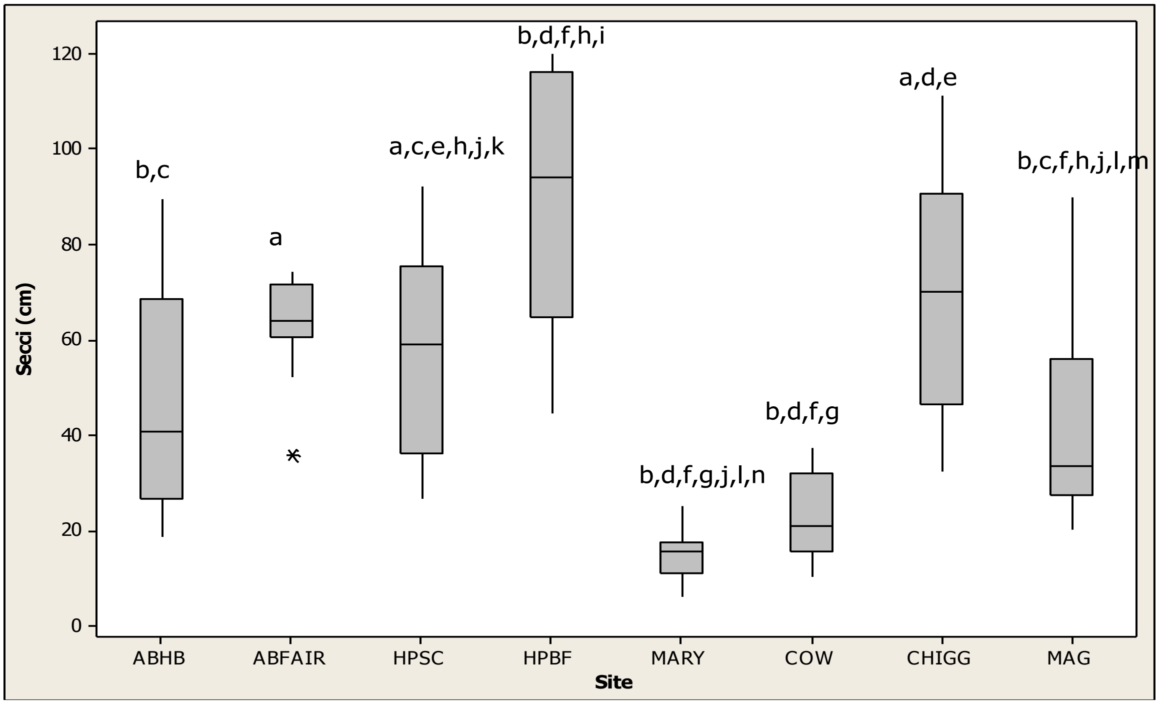

Figure 19: Water clarity from secchi (cm) combined for upstream, midstream, and downstream per site. Boxplots of interquartile range with median line. Whiskers represent highest and lowest data values; * represents outliers. Letters represent groups which are significantly different from ANOVA with Tukeys multiple comparison pairwise family test (alpha level= 0.05) comparison (p=0.000, R^2 =88.52)

Biological Results

During this study we collected 48,394 fish representing 45 species in seine collections, and 2,073 fish representing 23 species with electroshocking for a total of 50,467 fish and 45 total species. Three non-native fish species were collected including *Cichlasoma cyanoguttatum* (Rio Grande Cichlid) (1,220 specimens) from all sites, *Oreochromis sp*. (tilapia) (354 specimens) from all sites, and only 1 specimen of Loricariid catfish, from Horsepen at Space Center. The two cichlid species, Rio Grande cichlids and Tilapia, represented the fifth and eight most abundant species collected, respectively.

Fish Length Comparison

For both the seine and electroshocking data no significant correlation was found between cichlid and centrarchid lengths (Appendix IV).

Seine Catch Results:

The total numbers of fish per site are illustrated in Figure 20. The site MARY had both the highest number of fish caught and the highest mean. COW had the second highest number, almost half as many as MARY and a mean that was half the mean of the site MARY. ABHB had the lowest mean total number of fish out of all sites sampled.

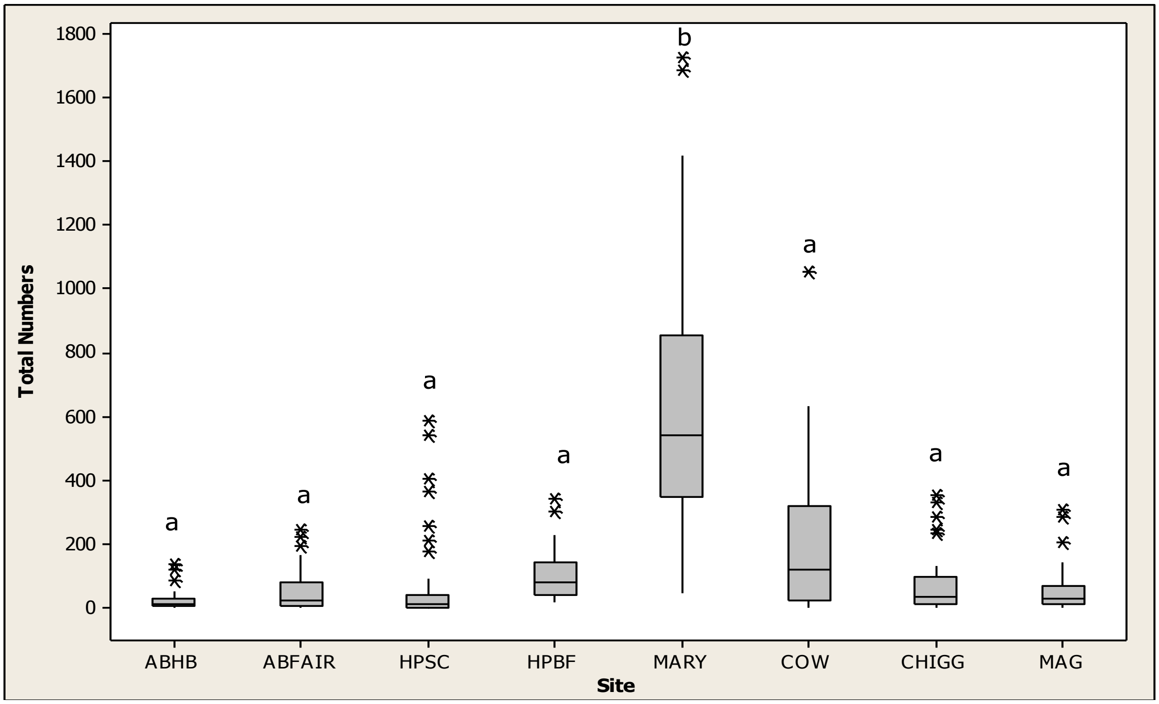

Figure 20: Total numbers of fish per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values, * represents outliers. Letters represent sites which are significantly different based on results of ANOVA (p=0.000, R^2=68.02) with Tukeys multiple comparison pairwise test (alpha level 0.05).

Cichlids, which include Tilapia and Rio Grand cichlids, were captured at all sites. The total number of cichlids captured per site during seining is illustrated in Figure 21. There is a significant difference in the number of cichlids between sites (p= 0.000). In addition, there is also a significant difference between months (p=0.019) and a significant interaction between sites and months (p=0.000). It does appear that the highest number of cichlids were captured at HPBF, followed by CHIGG and COW. HPSC had the lowest mean number of cichlids. Although the mean number of cichlids for all sites is less than 20, there was however considerable variation in catch rates with some samples having catches over 100.

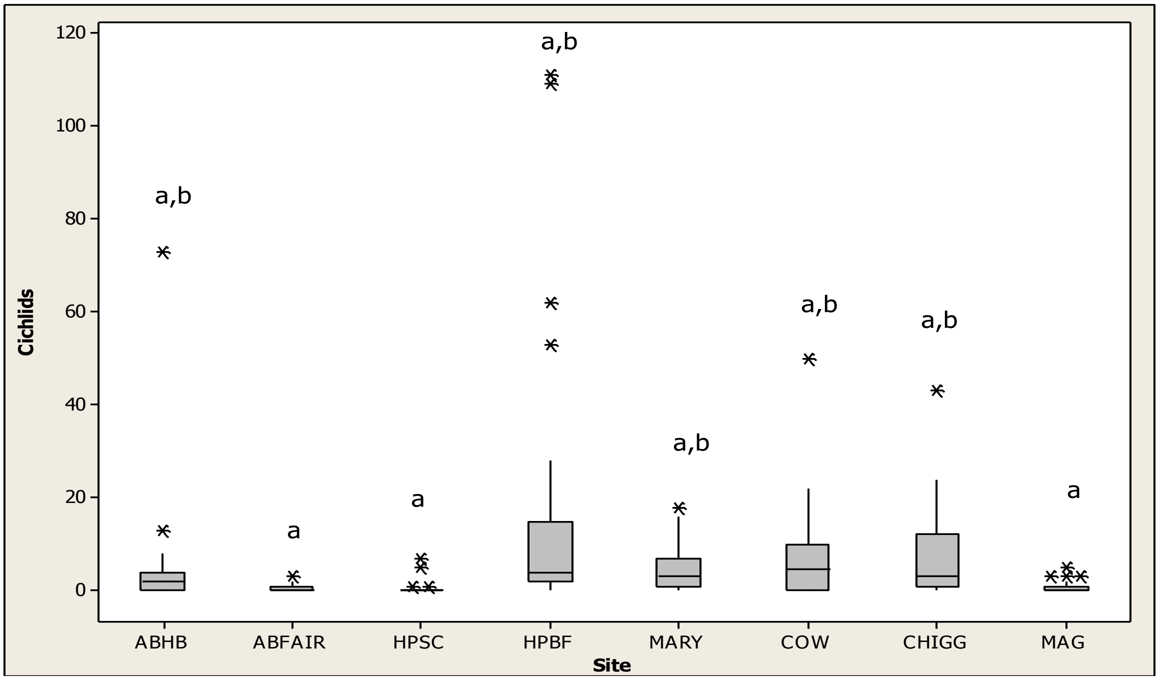

Figure 21: Number of Cichlids caught per site using a seine. Boxplot of interquartile range with median line. Whiskers represent highest and lowest data values * represents outliers. ANOVA results (p=0.000 R^2=34.25) with Tukeys multiple comparison pairwise family test (alpha level= 0.05).

The total numbers of centrarchids collected per site were all less than 30, with means of less than 5 per site (Figure 22). MARY had the highest mean number of centrarchids collected and CHIGG had the highest number of centrarchids with the second highest mean number. HPSC,HPBF, COW, and MAG all had mean catches of zero centrarchids. A significant difference was detected between sites using an ANOVA (p=0.000) and also between months (p=0.000). In addition, a significant interaction between sites and months (p=0.000) was also found. The streams in the Clear Creek watershed had higher numbers of centrarchids captured than those in the Armand Bayou watershed.

A significant but very weak correlation (Pearson's correlation = 0.158, p= 0.003) existed between centrarchid and cichlid catches (Figure 23). HPBF had greater numbers of cichlids, setting it apart from the rest of the sites. CHIGG was the only site that had both high average numbers of cichlids and high average numbers of centrarchids in the same sample.

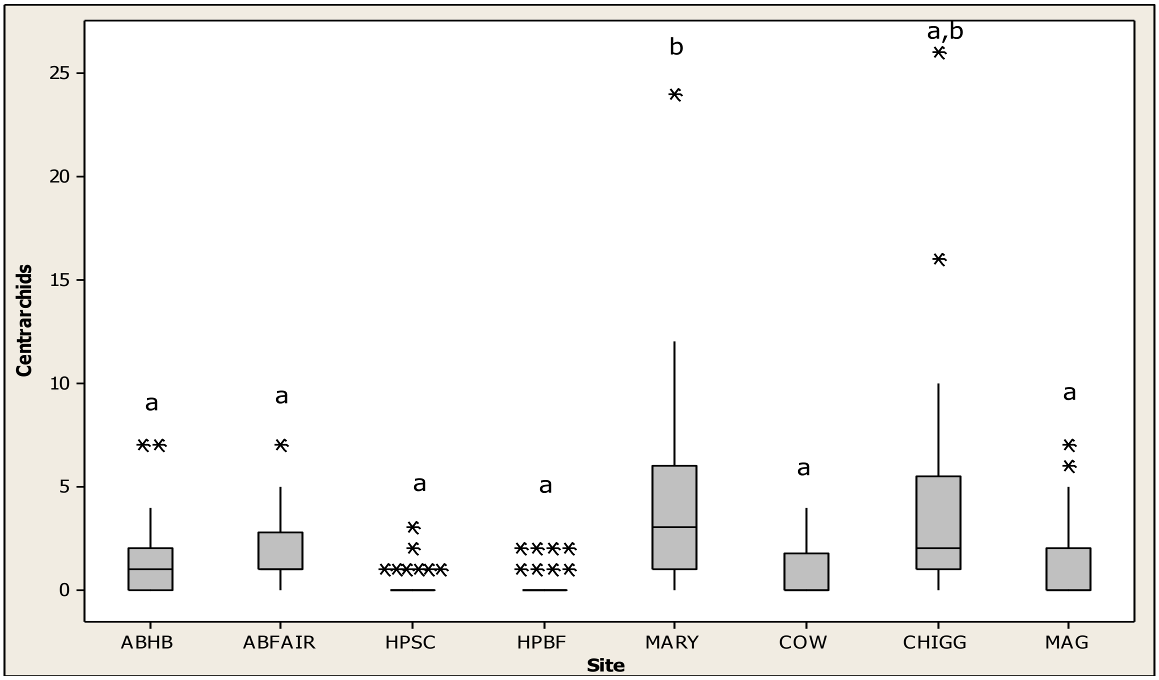

Figure 22: Number Centrarchids per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values, * represents outliers. Letters represent sites which are significantly different based on results of ANOVA (p=0.000, R^2=41.99) with Tukeys multiple comparison pairwise test (alpha level 0.05).

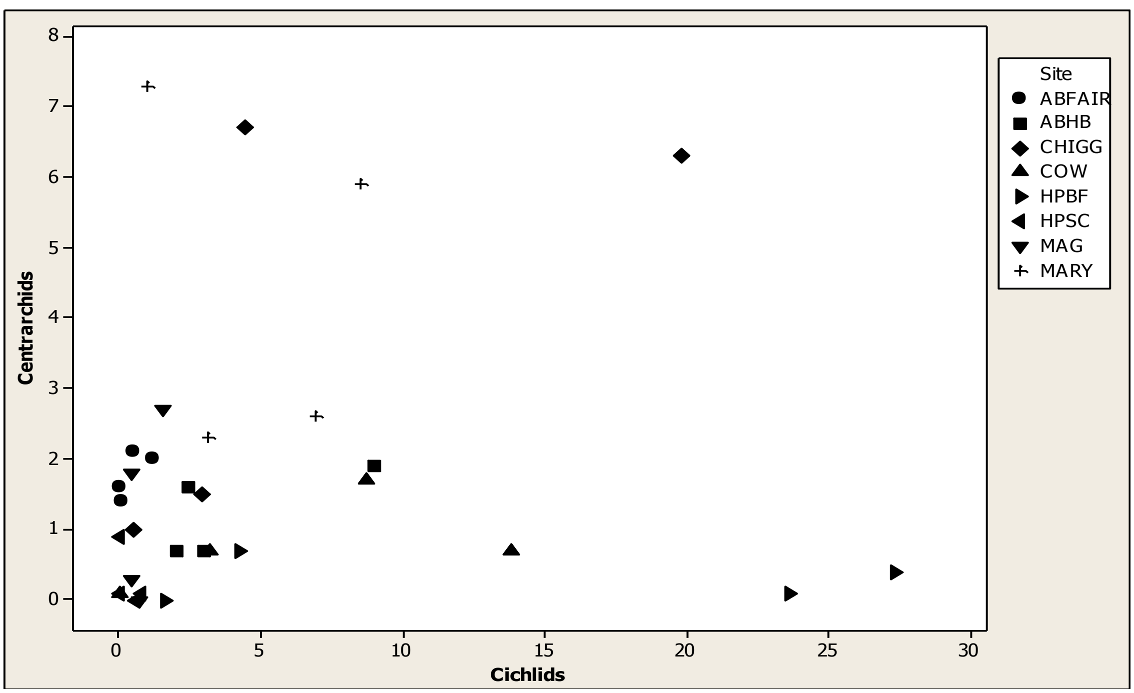

Figure 23: Average number of Cichlids versus Average number of Centrarchids per site based on seine collections. Pearson correlation= 0.118, p value= 0.521

The fish community diversity, measured using the Shannon-Wiener Index is illustrated in Figure 24, with MARY and HPBF having the least variation in diversity. CHIGG had the highest mean diversity of all sites with COW and MAG having the next highest mean diversity levels. ABFAIR had the lowest mean diversity. With the exception of the site MARY, the streams in the Clear Creek watershed had higher mean diversities than those located in the Armand Bayou watershed. The results of an ANOVA suggest that there is significant difference between sites (p=0.000), but not months. A significant interaction between sites and months does occur (p=0.000).

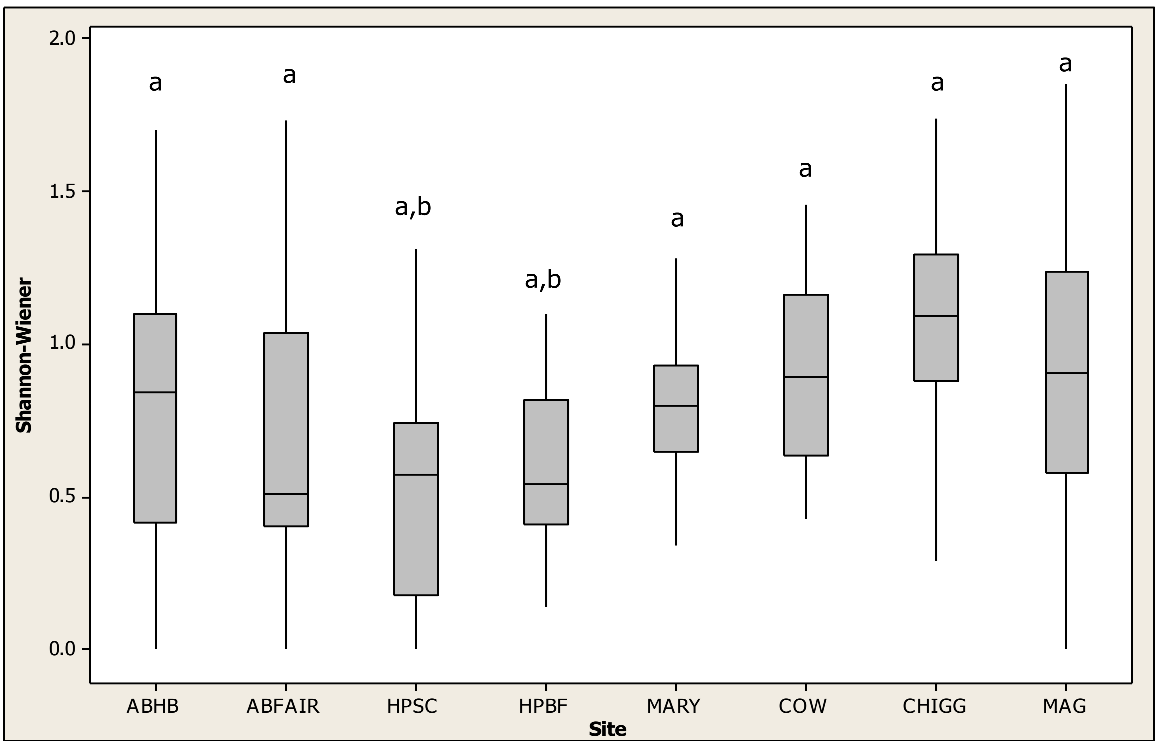

Figure 24: Fish Community Diversity per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values. ANOVA results (p=0.000, R^2=34.26) with Tukeys multiple comparison pairwise test (alpha level 0.05).

The site with the lowest community evenness was MARY (Figure 25). ABHB had the highest mean evenness score. The sites MARY and HPBF had less variation in community evenness than the other sites sampled. There was a significant difference between sites based on

ANOVA results (p=0.000) as well as between months (p=0.000). A significant interaction between sites and months also occurs (p=0.000).

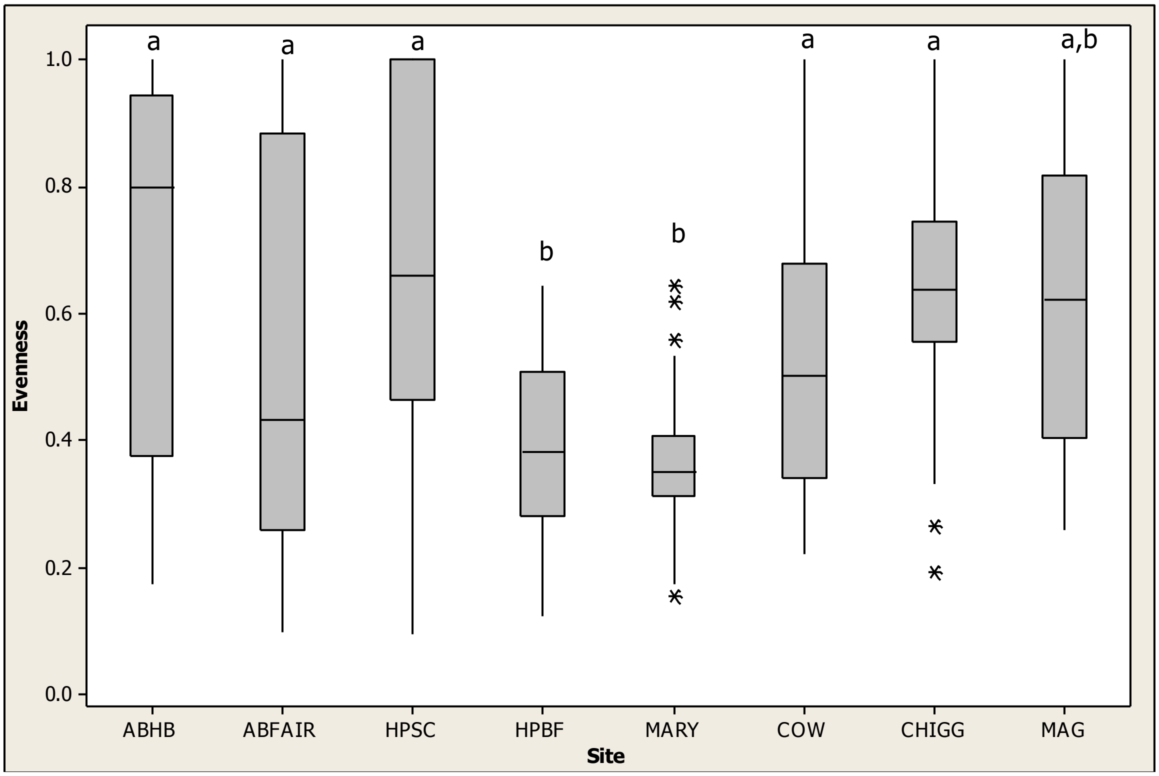

Figure 25: Evenness per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values, * represents outliers. Letters represent sites which are significantly different based on results of ANOVA (p=0.000, R^2=53.00) with Tukeys multiple comparison pairwise test (alpha level 0.05).

Community richness was lower in the Armand Bayou sites than the Clear Creek sites (Figure 26). The site Mary had the highest mean community richness scores, whereas HPSC had the lowest mean community richness scores. Although the results of the ANOVA show a significant difference between sites for fish community richness (p=0.000) there is also a significant difference between months(p=0.000) and a significant interaction between sites and months (p=0.000).

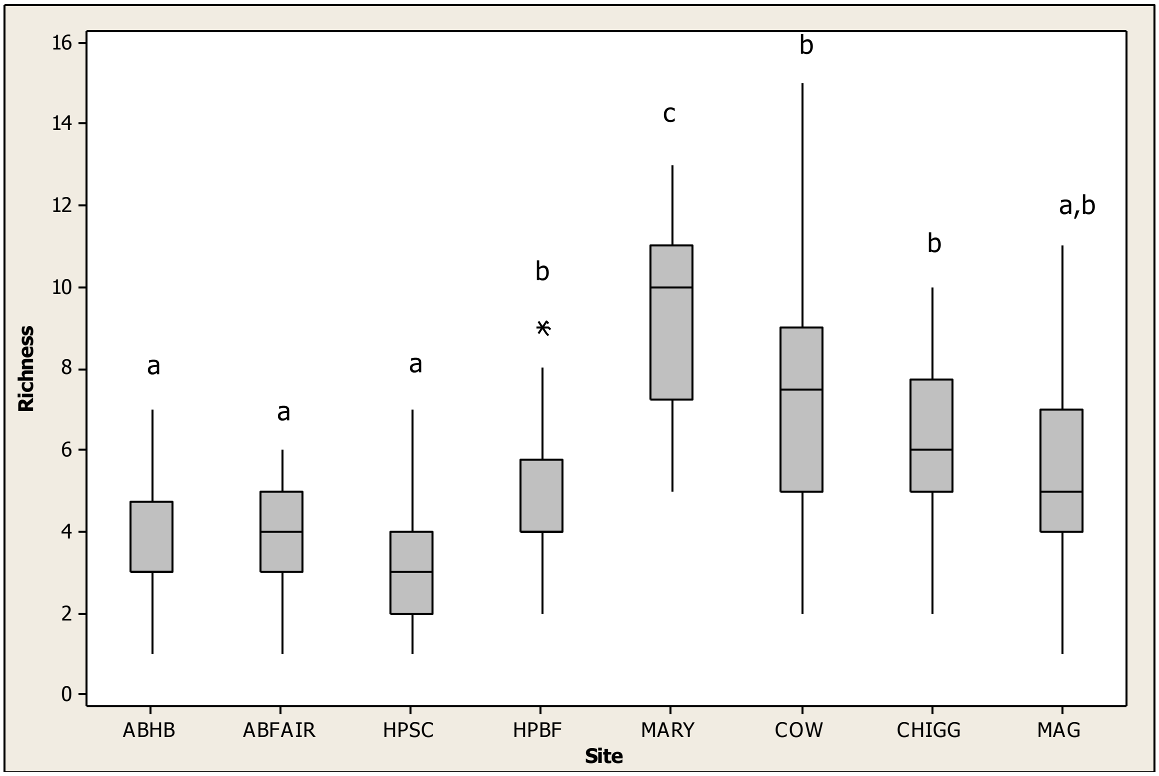

Figure 26: Richness per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values, * represents outliers. Letters represent sites which are significantly different based on results of ANOVA (p=0.000, R^2 = 71.20) with Tukeys multiple comparison pairwise test (alpha level 0.05).

Figures 27–29 illustrate the relationship between the fish community and cichlids captured while seining. No significant correlation was detected between these variables.

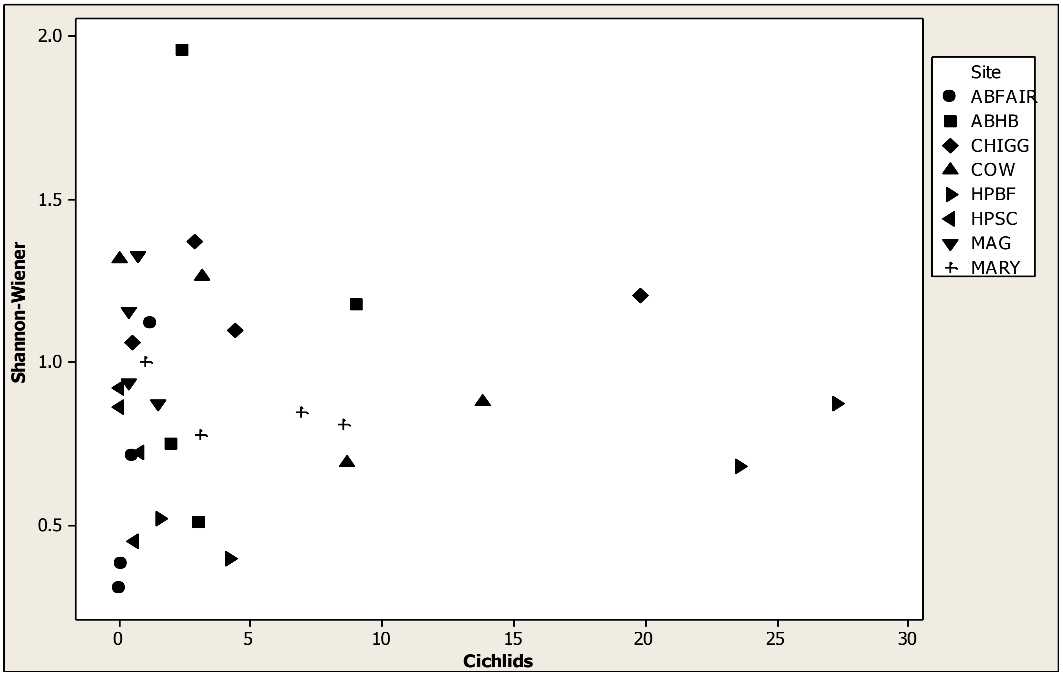

Figure 27: Average number of Cichlids versus average fish community Shannon-Wiener Diversity per site based on seine collections. Pearson correlation= 0.003, p value= 0.986.

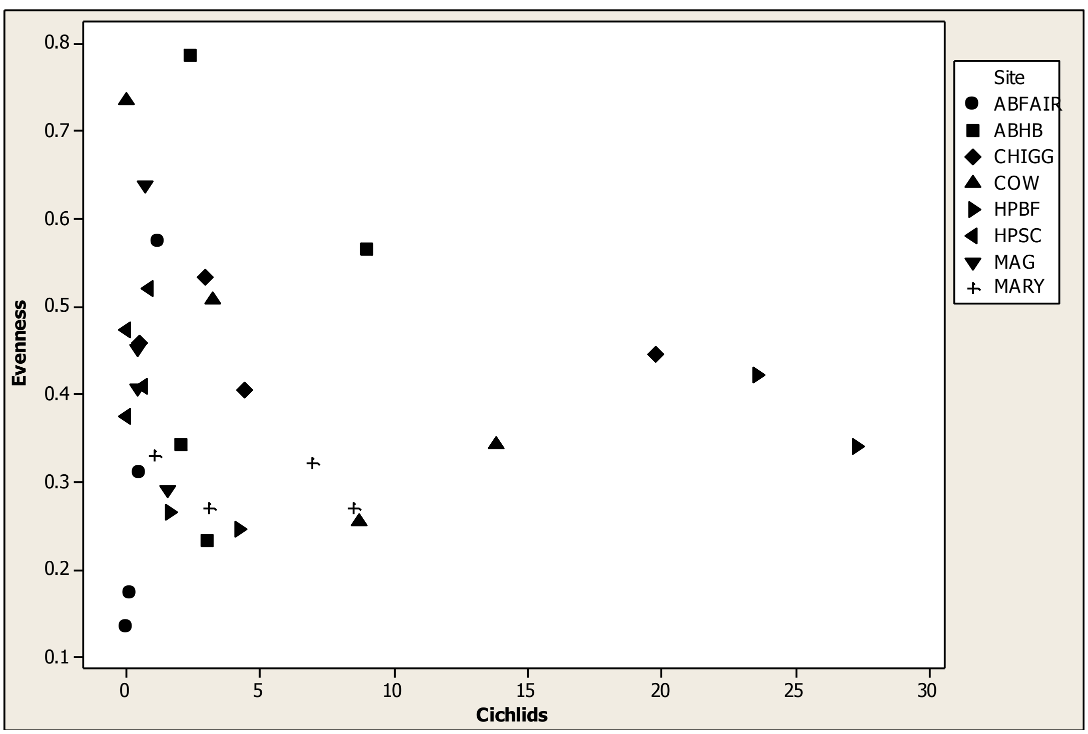

Figure 28: Average number of Cichlids versus average fish community Evenness per site based on seine collections. Pearson correlation= -0.077, p value= 0.676.

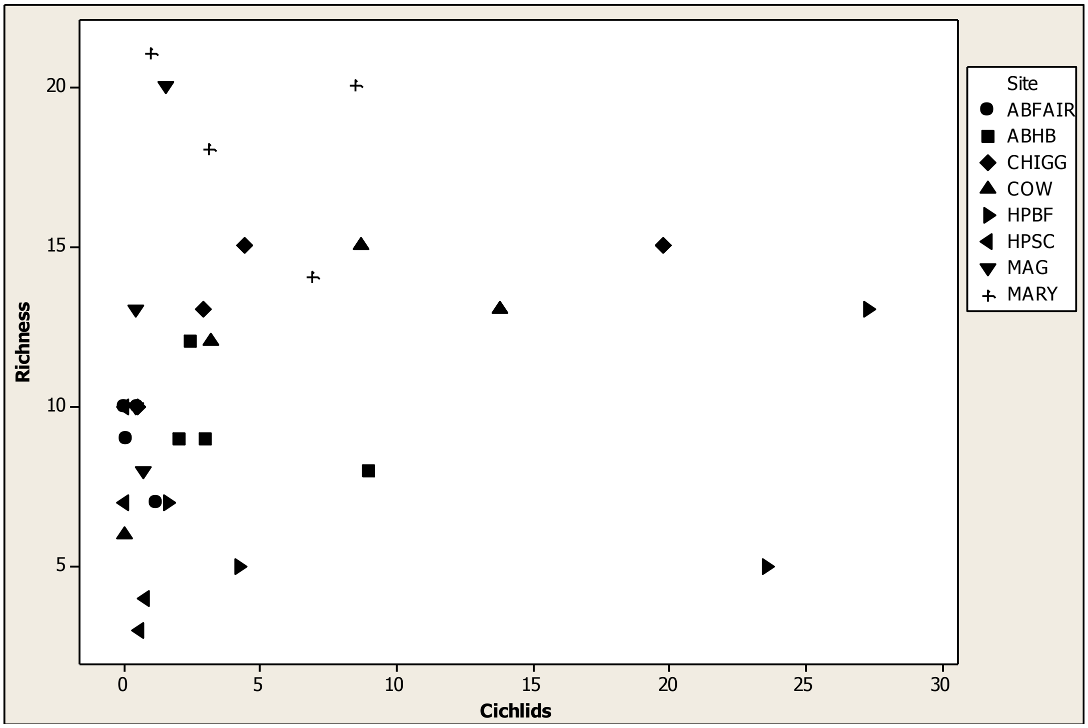

Figure 29: Average number of Cichlids versus average fish community Richness per site based on seine collections. Pearson correlation= 0.141, p value= 0.441.

For all fish community and average cichlid correlations, HPBF (2 seine samples) and CHIGG (1 seine sample) varied from the rest of the samples due to high average cichlid catches with >15 cichlids in each sample.

A cluster analysis was conducted on biological data using average density per species per collection for seine data, using Minitab 15. Prior to cluster analysis we reduced the data matrix by using only those species that occurred in greater than 5% of the samples. This same data was run in Clustan, which uses an algorithm to validate where to cut the clusters. Three clusters were designated significant by the Clustan software. These are shown in Figure 30. The sites Marys1 (June), Cowards 3 (August) and Coward's 4 (September) make up cluster 2, the common biological characteristic is that they all had over 2000 *Gambusia affinis*. The other three Mary's samples have over 4000 *G. affinis* making up cluster 3. All other sites ranged from 1 to 1,382 *G. affinis* per collection. A stepwise discriminant analysis was also conducted using SPSS 15.0 to determine what combination of physical and water quality variables best separate and predict cluster group designation. For the seining data both pH and average stream width appeared to best predict cluster membership (Appendix VIII).

The same biological and environmental data set was analyzed using Principal Components Analysis (PCA) to determine the relationship between biological, physical, and hydrological variables. A biplot showing the component scores of individual collections and variable loading on the first two components are depicted in Figure 31. The results of the PCA show that all four collections from Mary's Creek exhibited high principal component 1 scores and were grouped together, separate from the other sites. COW and ABFAIR in July (month 2) also appeared to exhibit extreme principal component 2 scores, above and below the remaining sites, respectively. The first principal component appeared to reflect the inverse relationship between the first group of variables which includes phosphate, percent run, stream width, and conductivity and the second group of variables which includes habitat complexity, stream clarity, percent pool, percent riffle, ammonia nitrogen and sediment size. As previously mentioned, sites such as Mary's Creek, lacked habitat complexity and were generally wide segments consisting of slow flowing runs. The second principal component appeared to reflect the inverse relationship between the first group of variables which includes submerged vegetation, evenness, diversity, nitrate, stream velocity, and stream depth, and the second group of variables which includes total numbers of fish, dissolved oxygen, cichlid abundance, emergent vegetation, richness, pH, centrarchid abundance and stream temperature.

A stepwise regression was also conducted on the same data. Centrarchid abundance is influenced by average stream width, phosphate, conductivity, habitat complexity, average percent emergent vegetation and ammonia. The fish community indices diversity and evenness were both influenced by average percent emergent vegetation, pH, dissolved oxygen and cichlid abundance. Diversity was also influenced by nitrate levels. Richness was only influenced by average stream width, average percent emergent vegetation and nitrates. Average stream width, pH, cichlid abundance, water clarity and sediment size (Wentworth scale) all influenced the total number of fish collected. Cichlids were influenced by fish community richness, conductivity, alkalinity, pH, water temperature and salinity (Appendix XII). These results also support the results of the principal components analysis.

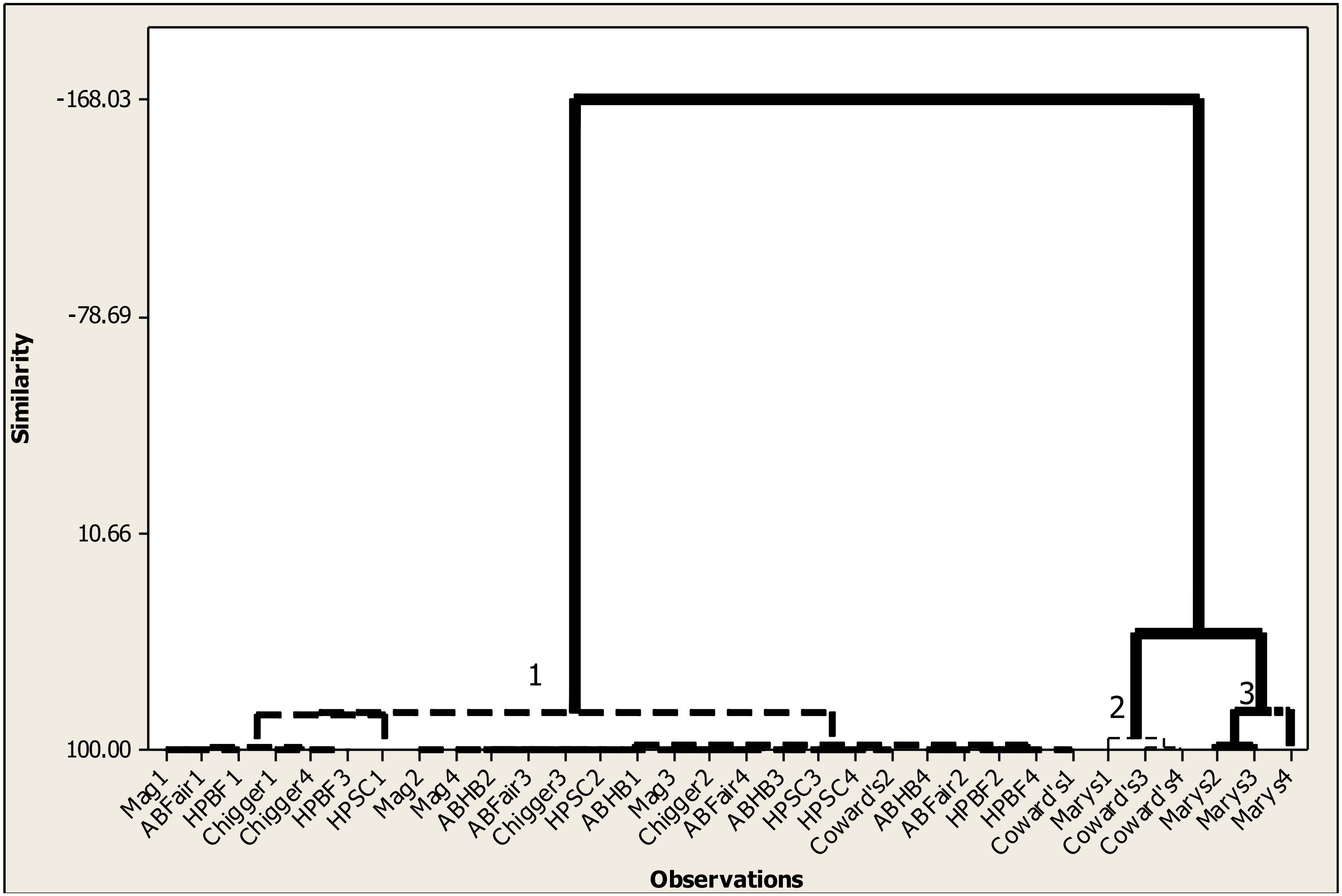

Figure 30: Seine data cluster analysis with numbers representing cluster designations based on fish community composition.

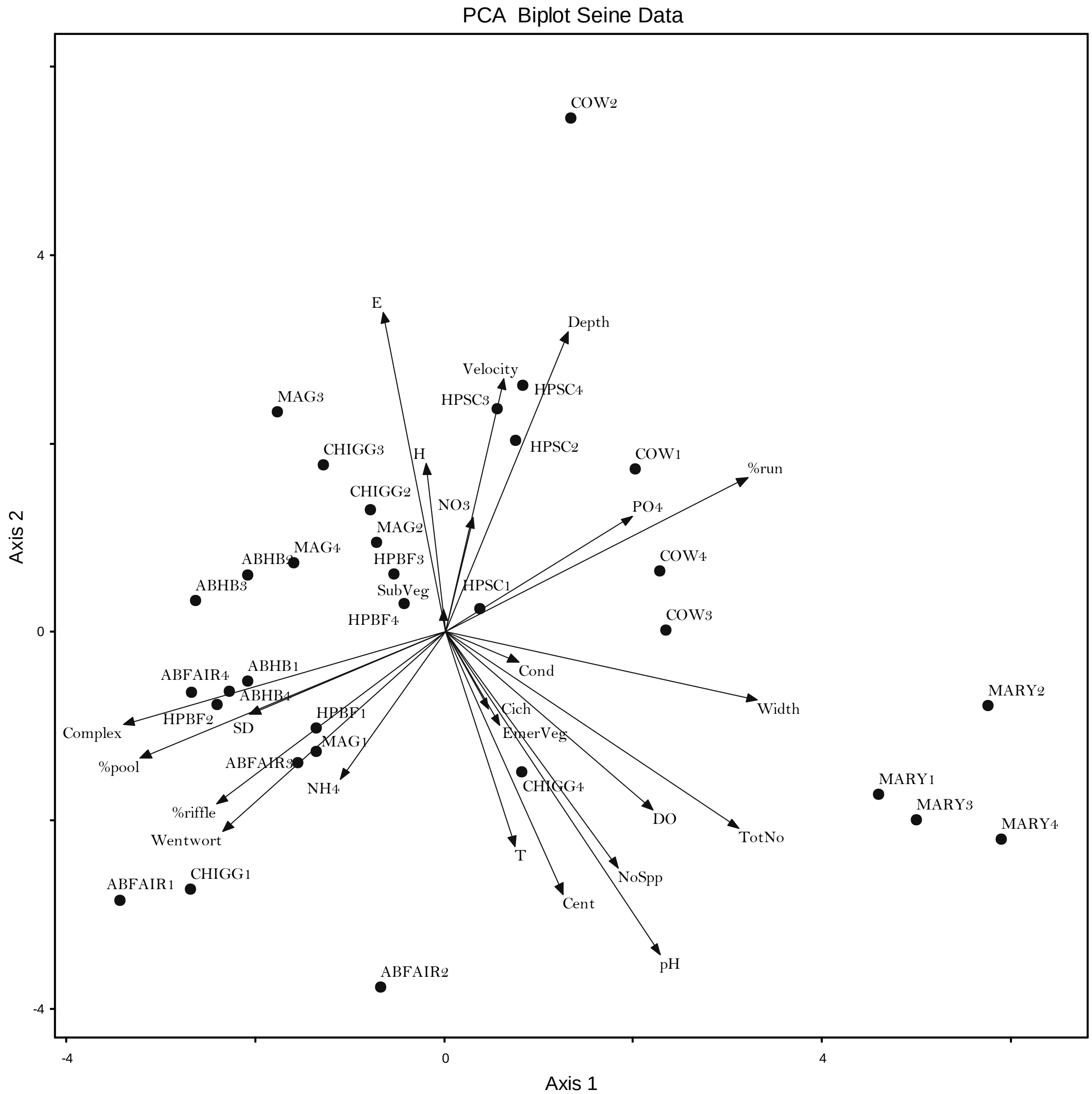

Figure 31: Principal Components Analysis (PCA) biplot depicting the relative loading of each variable for principal component 1 and principal component 2 and site scores for seine collection data.

Electroshocking Results:

The site with the highest total numbers and mean total numbers of fish was CHIGG, with MARY having the next highest numbers (Figure 32). MARY also had the most variation and HPSC had the least variation in numbers of fish captured. ABFAIR had the lowest mean total numbers of fish captures per site. An ANOVA was unable to be conducted on the electroshocking data due to uneven sampling effort.

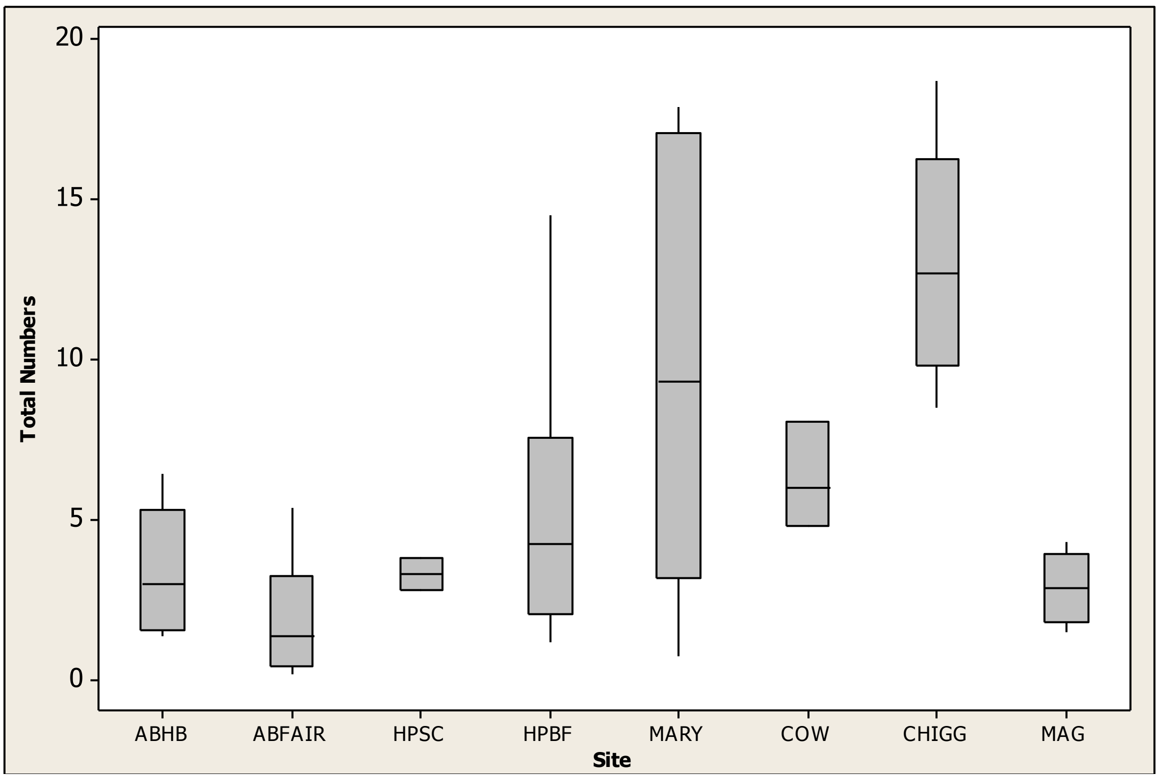

Figure 32: Total Numbers per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values.

The CPUE (#/min) of cichlids captured during electroshocking is shown in Figure 33. The sites with the highest CPUE of cichlids (HPBF, COW, and CHIGG) were the same as that for seining. ABFAIR, HPSC and MARY had no cichlids captured during electroshocking. MAG and CHIGG had mean cichlid catches of zero.

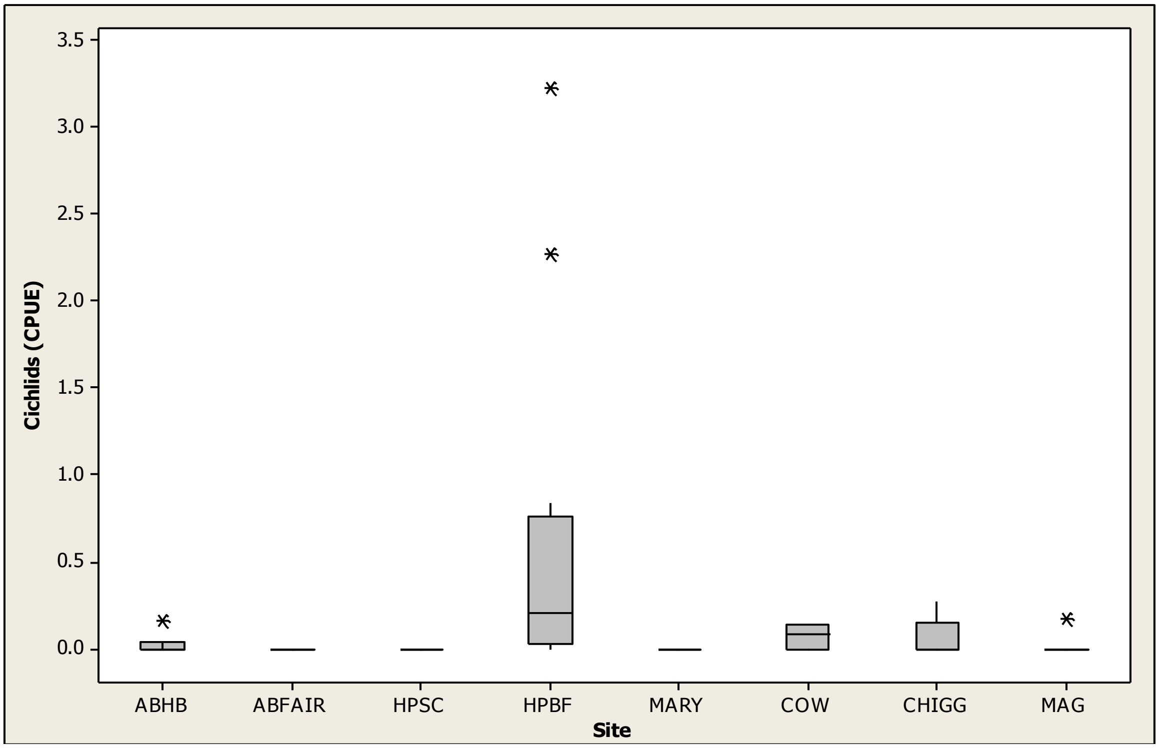

Figure 33: Cichlids (CPUE) per site collected by electroshocking. Boxplot of interquartile range with median line. Whiskers represent highest and lowest data values; * represents outliers.

HPBF, MARY, and COW had no centrarchids captured during electroshocking (Figure 34). HPSC and ABFAIR both had mean CPUE of zero centrarchids. MAG had the highest mean CPUE of centrarchids captured and the most variation in capture rates. No significant correlation was detected between the CPUE Cichlids and the CPUE centrarchids for electroshocking (Figure 35).

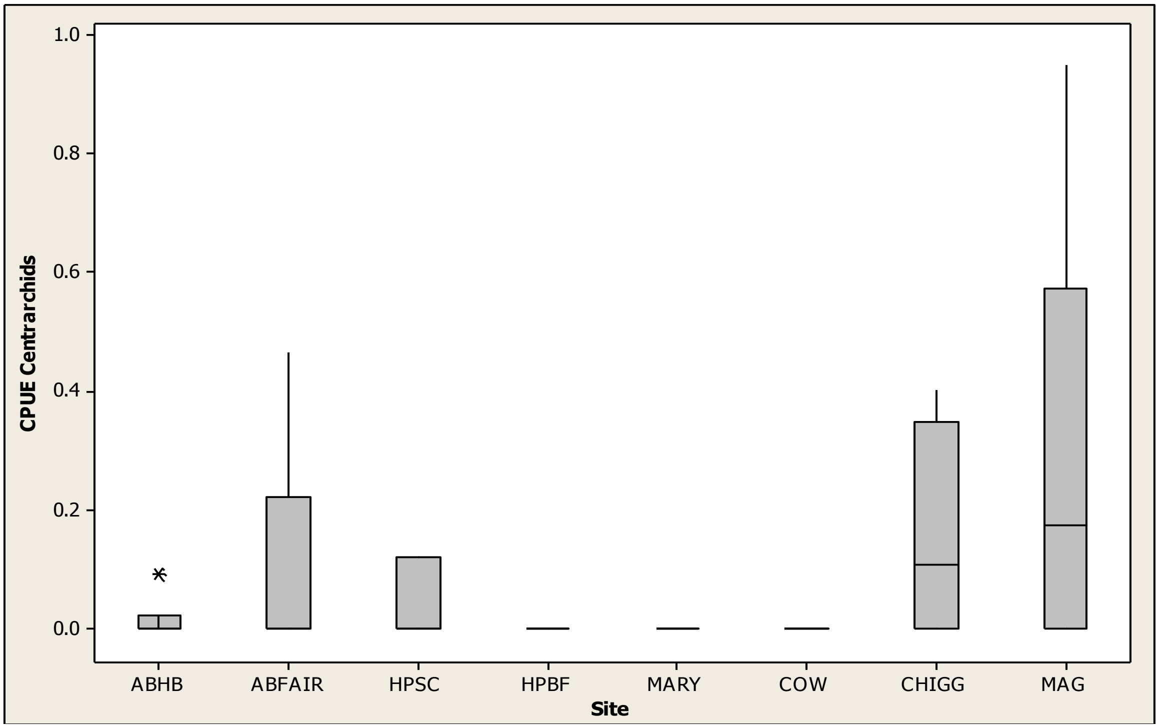

Figure 34: CPUE Centrarchids per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values, * represents outliers.

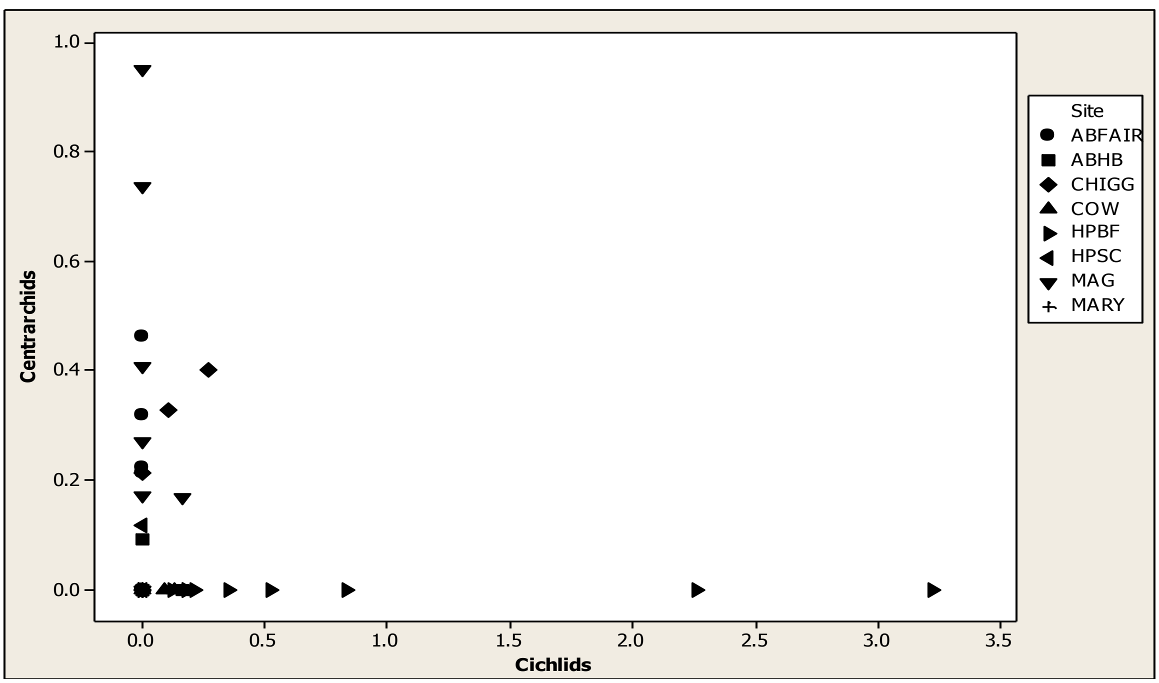

Figure 35: CPUE Cichlids versus CPUE Centrarchids per site based on electroshocking collections. Pearson correlation= -0.110, p value= 0.417

The Shannon-Wiener fish community diversity CPUE per site is illustrated in Figure 36. MAG had the highest fish community diversity CPUE for electroshocking. ABHB had the lowest fish community diversity and MARY had the next lowest diversity. HPSC had very little variation in fish community diversity between samples.

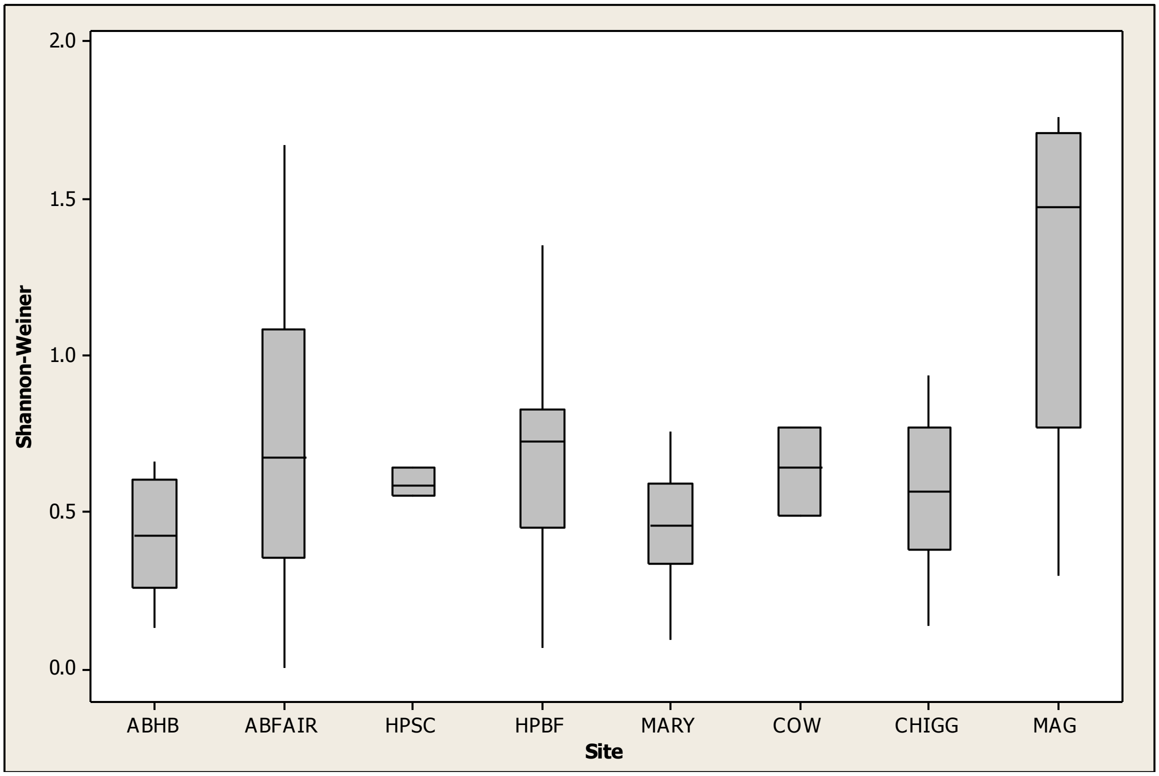

Figure 36: Fish Community Diversity CPUE per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values.

ABFAIR had the highest mean evenness scores for electroshocking (Figure 37). MAG had the next highest mean evenness scores. CHIGG had the lowest mean evenness for electroshocking. HPSC had the least variation between samples for fish community evenness.

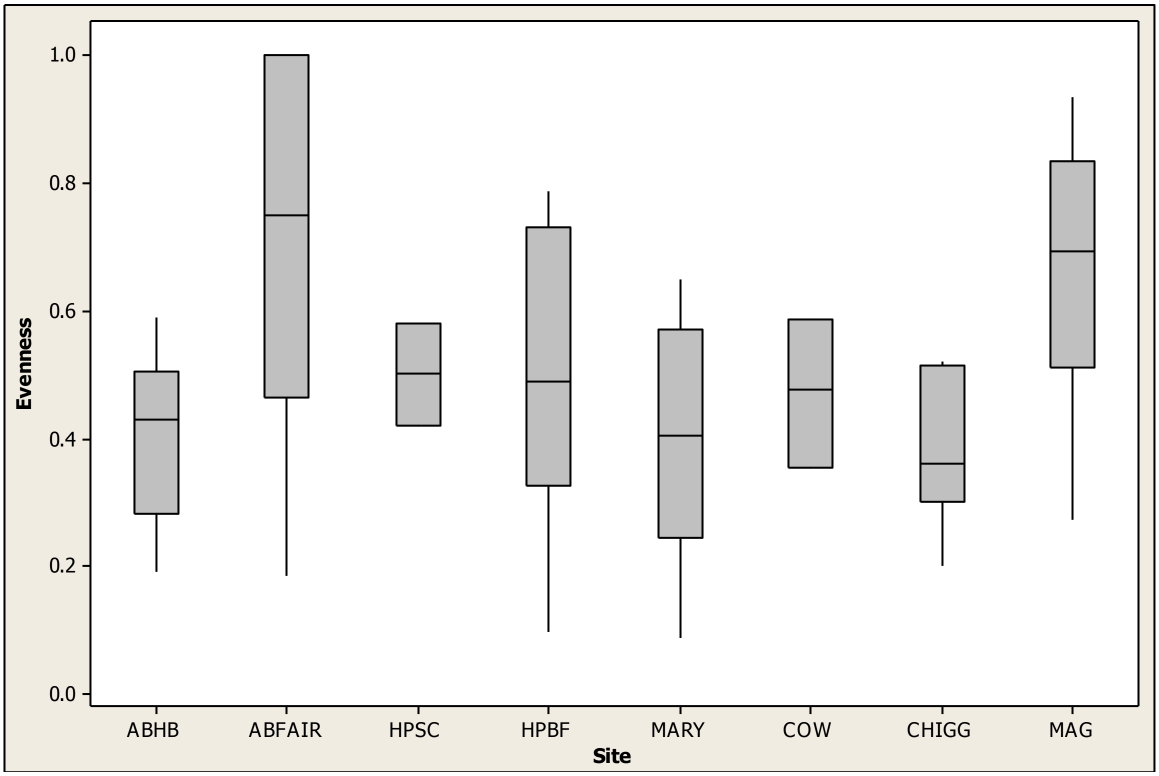

Figure 37: Evenness per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values.

The mean fish community richness per site increased going downstream through the Clear Creek watershed (Figure 38). Armand Bayou also has a slight increase in fish community richness moving downstream. MAG has the highest fish community richness scores for electroshocking and the most variation in samples. HPSC has the least variation, as seen with fish community diversity and evenness. ABHB, ABFAIR, and HPSC have the lowest fish community richness for the electroshocking samples.

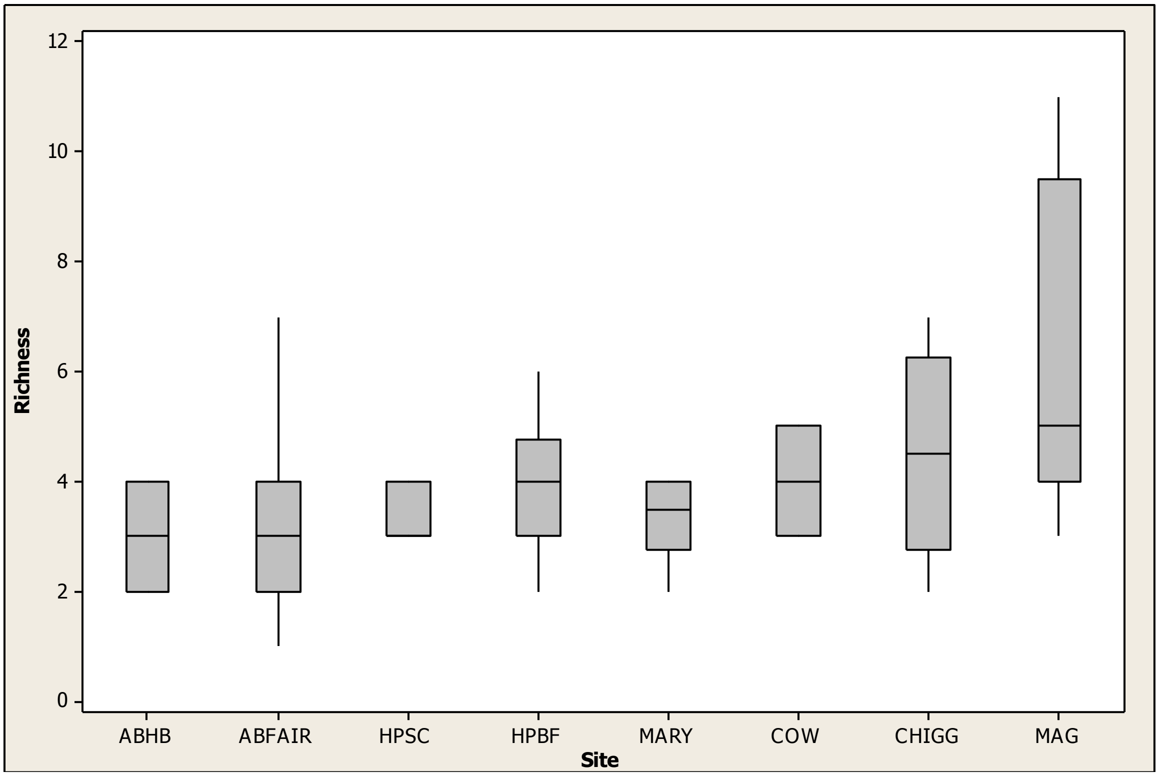

Figure 38: Richness per site. Boxplots of interquartile range with median line and whiskers representing highest and lowest data values.

Figures 39 through 41 show the relationship between the fish community and cichlids captured while electroshocking. A significant correlation existed between CPUE cichlids and fish community diversity (Pearson's = 0.043, p value = 0.751). The fish community evenness and CPUE cichlids had a significant correlation (Pearson's = 0.048, p value = 0.724) as well. In addition, a significant negative correlation also existed between the fish community richness and CPUE cichlids (Pearson's = -0.017, p value = 0.902) for electroshocking samples. The HPBF sites were extremely variable based on the high number of outlier values for all indices evaluated.

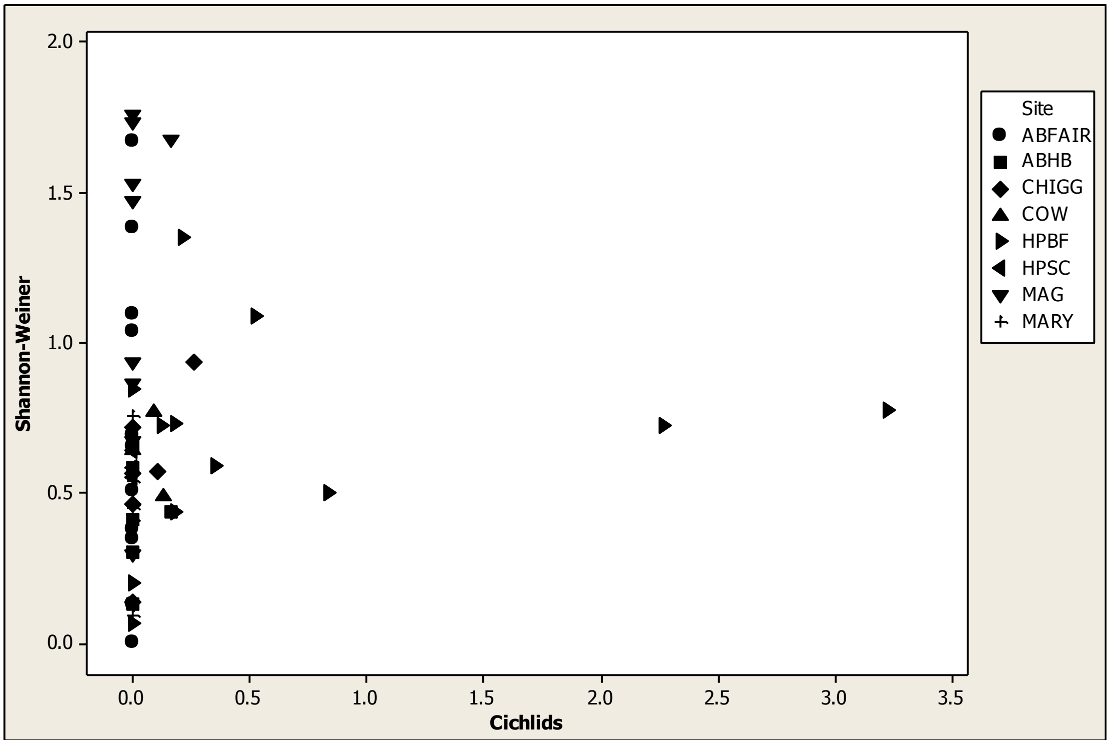

Figure 39: CPUE Cichlids versus fish community Shannon-Wiener Diversity (CPUE) per site based on electroshocking collections. Pearson correlation= 0.043, p value = 0.751

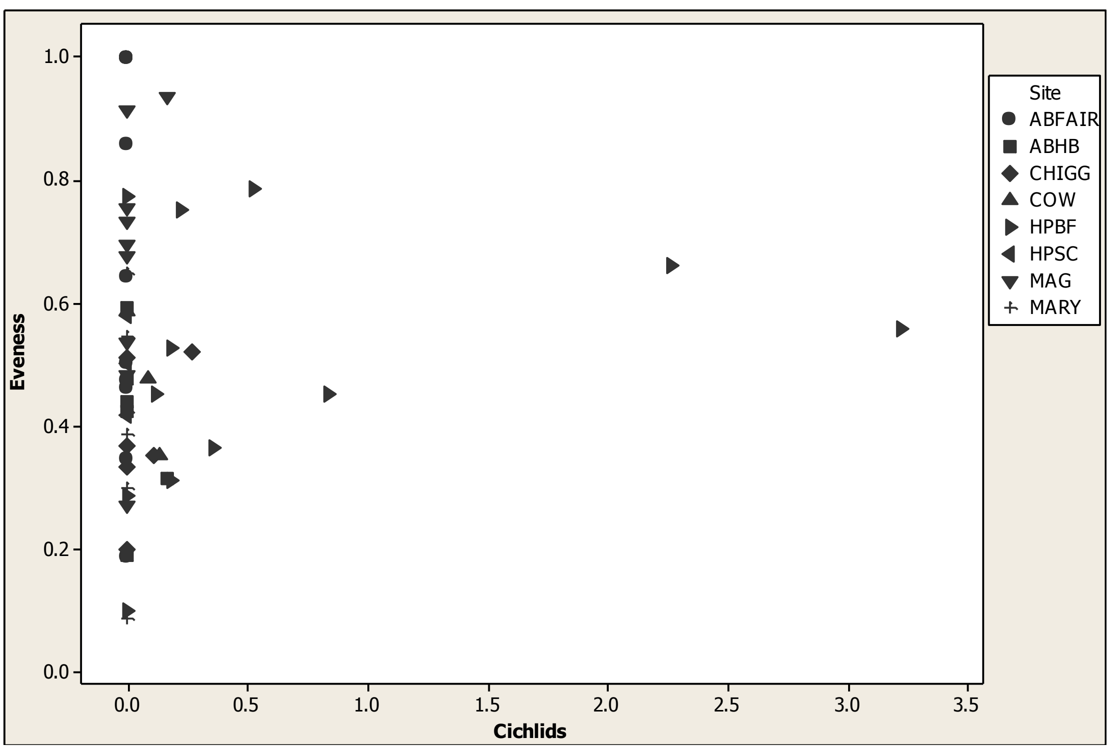

Figure 40: CPUE Cichlids versus fish community Evenness (CPUE) per site based on electroshocking collections. Pearson correlation= 0.048, p value= 0.724.

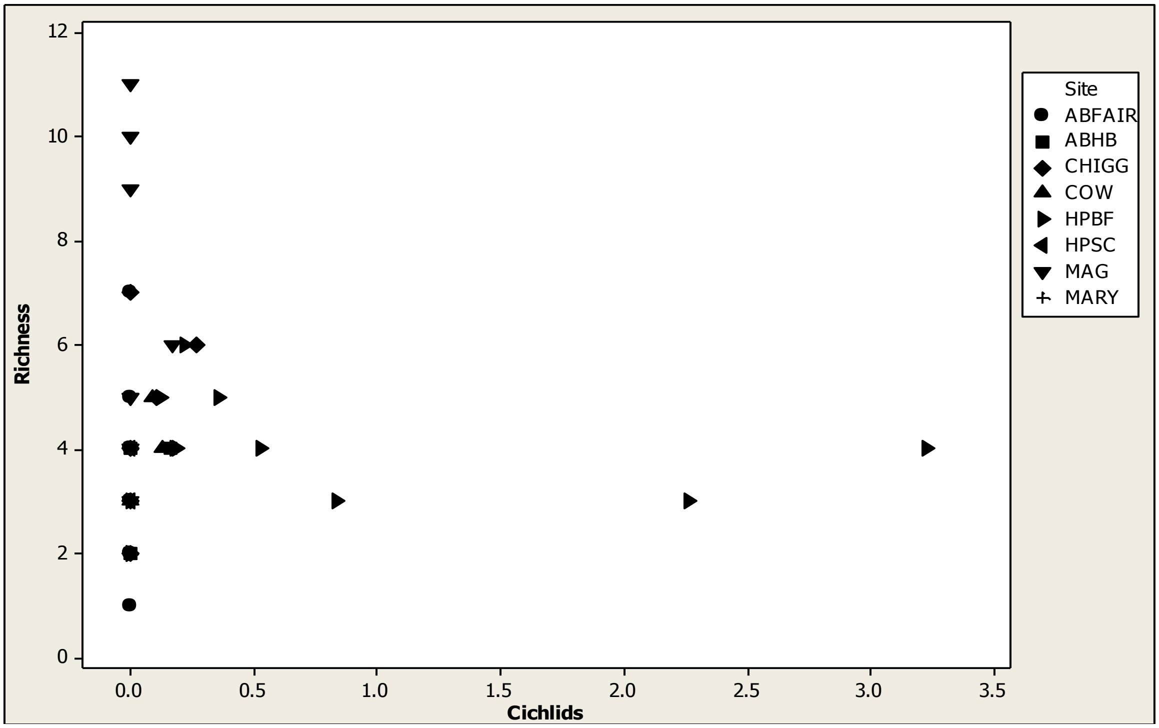

Figure 41: CPUE Cichlids versus fish community Richness (CPUE) per site based on electroshocking collections. Pearson correlation= -0.017, p value= 0.902

A cluster analysis was conducted on biological data using average CPUE density per species per collection for electroshocking data, using Minitab 15. Prior to cluster analysis we reduced the data matrix by using only those species that occurred in greater than 5% of the samples. This same data was run in Clustan, which uses an algorithm to validate where to cut the clusters. Five clusters were designated significant by the Clustan software. These are shown in Figure 42. A stepwise discriminant analysis was also conducted using SPSS 15.0 to determine what combination of physical and water quality variables best separate and predict cluster group designation. For the electroshocking data only habitat complexity appeared to best predict cluster membership (Appendix VIII).

The same biological and environmental data set was analyzed using Principal Components Analysis (PCA) to determine the relationship between biological, physical, and hydrological variables. A biplot showing the component scores of individual collections and variable loadings on the first two components are depicted in Figure 43. The results of the PCA show that the collections from the site MARY for months 1 (June) and 4 (September) exhibited high principal component 1 scores and were grouped together, separate from the other sites. The collection for MAG month 1 (June) exhibited low principal component 1 scores and high principal component 2 scores; therefore it is also separated from the other sites. The first principal component appeared to reflect the inverse relationship between the first group of variables which includes dissolved oxygen, total catch, pH, nitrates, width, emergent vegetation, depth, Cichlids, phosphate, conductivity, percent pool and the second group of variables which includes habitat complexity, sediment size, stream clarity, percent pool, and percent riffle. The second principal component appeared to reflect the inverse relationship between the first group of variables which includes water temperature, ammonia nitrogen and the second group of variables which includes evenness, diversity, richness, centrarchids, submerged vegetation, and stream velocity.

A stepwise regression was also conducted on the same data. Centrarchid abundance was influenced by the average percent emergent vegetation, average stream thalweg velocity, dissolved oxygen, pH, conductivity, cichlid abundance, and nitrate. Fish community diversity was influenced by average stream thalweg velocity, habitat complexity, water temperature, average percent emergent vegetation, water clarity and conductivity. Fish community evenness was influenced by habitat complexity, average percent emergent vegetation, average stream width, and phosphate levels. Average percent submerged vegetation, average stream velocity, average percent emergent vegetation, conductivity, water clarity, and nitrate levels influenced the fish community richness. Total numbers of fish were influenced by habitat complexity, average percent emergent vegetation, average stream depth, nitrate, pH, water clarity, ammonia, and cichlid abundance. The cichlid abundance for electroshocking samples was influenced by dissolved oxygen, nitrate, conductivity and the average percent submerged vegetation. These results also support the results of the principal components analysis.

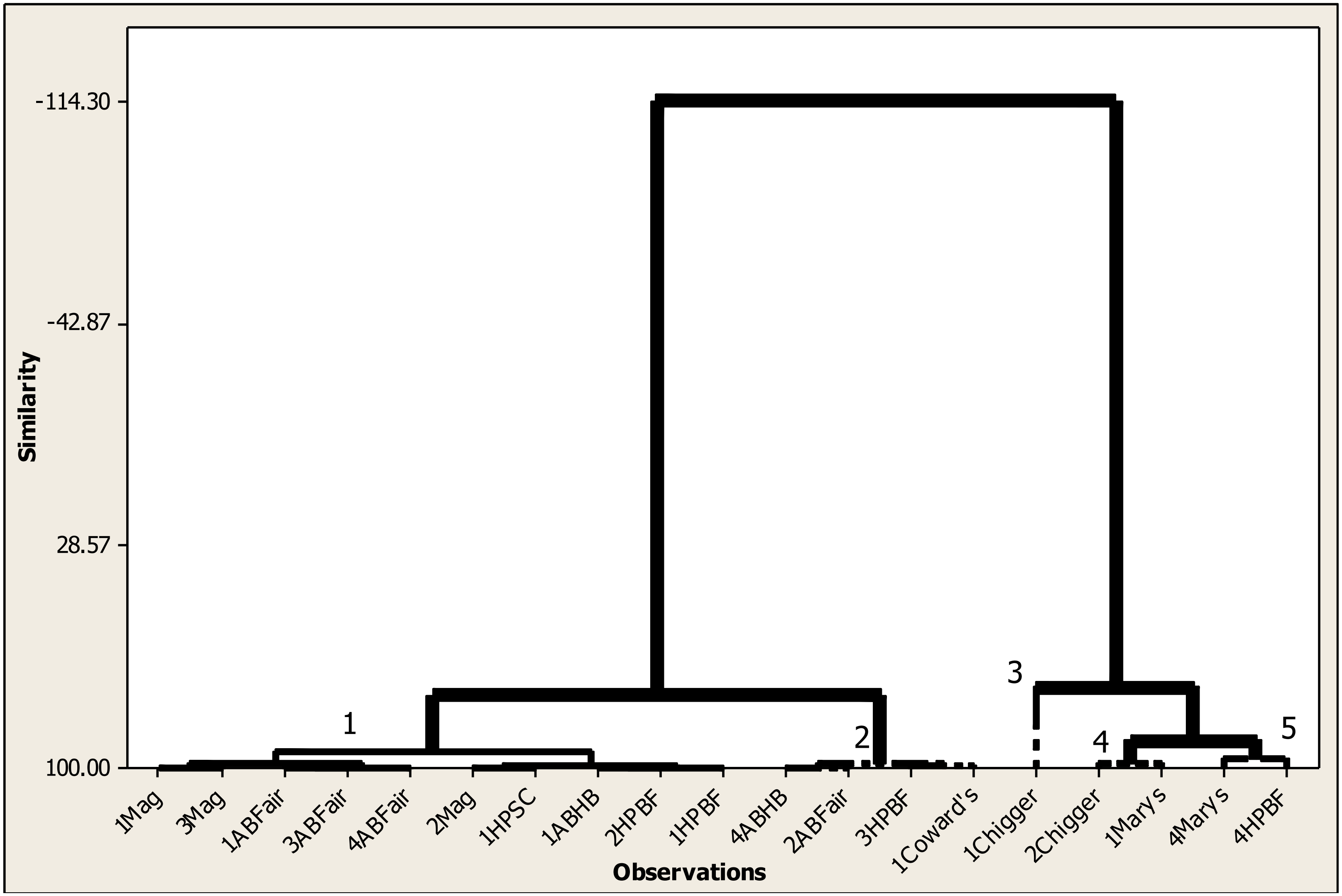

Figure 42: Electroshocking data cluster analysis with numbers representing cluster designations based on fish community composition. The cluster analysis was conducted using fish species data (CPUE) for each sampling station per month.

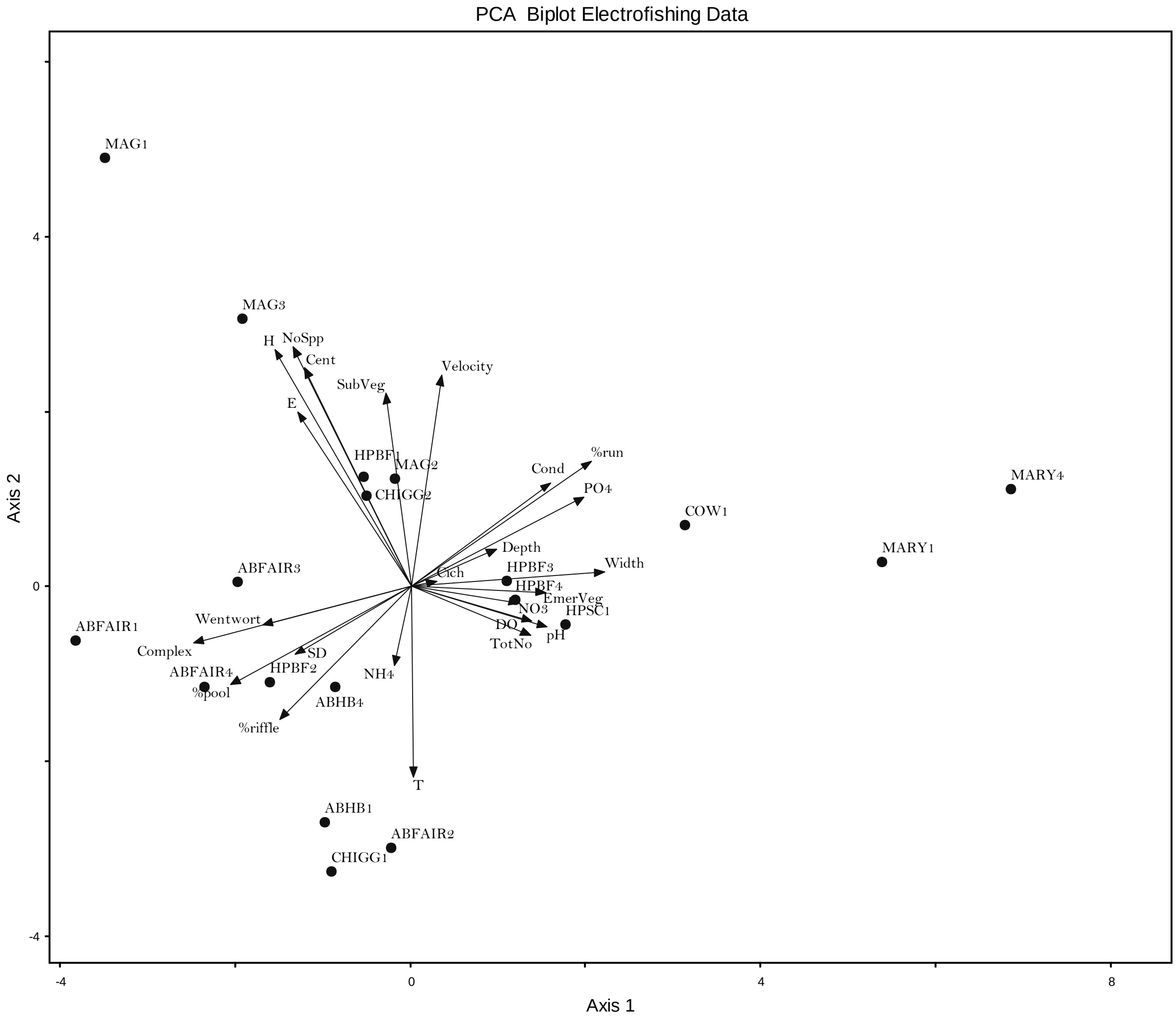

Figure 43: Principal Components Analysis (PCA) biplot depicting the relative loading of each variable for principal component 1 and principal component 2 and site scores for electroshocking collection data.

Discussion:

In this study, the sites with the highest abundance of cichlids per site for both seining and electroshocking were Horsepen at Brookforest, Chigger, and Coward's. These sites were outliers for all the community indices, such as diversity, evenness and richness. These three sites all also had mean dissolved oxygen levels under 4mg/L. *Oreochromis sp*. (Tilapia) and *Cichlasoma cyanoguttatum*, Rio Grande cichlids, were found at all sites. The Rio Grande cichlids and Tilapia were the fifth and eighth most abundant fish collected, respectively. Only one specimen of Loricariid catfish was collected during this study, but their presence in the Clear Lake watershed has been documented by more recent studies conducted by the Biology of Fishes and Marine Biology classes at the University of Houston, Clear Lake using different collecting gear (Guillen pers. comm.)

The affect of human disturbance in the Clear Lake watershed is evident by the amount of development within the watershed. Mean sediment was clay/silt for all sample sites except ABFair. The channelization of the streams in this study is typical of urban waterbodies throughout the Galveston Bay watershed. In addition to the alteration of flow that channelization has, the amount of submerged and emergent vegetation has also been negatively effected. We saw decreased amounts of in stream vegetation in these channelized streams, for example at all transects the stream had <50% submerged vegetation at all sample sites. This has also been observed and recorded by other investigators (Bryan & Rutherford, 1993). Overall the stream slopes for all sites were fairly steep. This can lead to increased erosion, adding to the stream degradation. Within the Clear Creek watershed stream width decreased moving downstream, with the site Mary being the widest of all sites sampled in either watershed.

Not only are habitat alterations occurring, but water quality is affected as well. Wastewater effluent effects include increased phosphate, nitrate, and temperature. Two of the sites with wastewater loading, HPSC and MARY sites, did have elevated phosphate and nitrate levels compared to our other sites. Temperature did have a positive relationship with invasive cichlid abundance. MARY also had increased pH that could be due to eutrophication from the wastewater loading.

The Clear Creek watershed had higher centrarchid abundance than the Armand Bayou watershed. In turn, the fish community richness was lower in the Armand bayou watershed than the Clear Creek watershed. Fish community richness increased moving downstream in both the Clear Creek and Armand Bayou watersheds.

The presence of invasive cichlids appears to be negatively correlated with overall fish community diversity, evenness, and richness. It is highly likely that they are having a negative effect on the native fish community. Electroshocking collections documented a negative relationship between the invasive cichlids and the native centrarchids.

Invasive fish species are a major problem in the United States today. Not only are these invaders costly, but they are altering the ecosystems into which they are introduced. This study has shown that the presence of invasive cichlids can have a negative relationship with fish community evenness, richness, and overall diversity. The electroshocking PCA data has also shown that the invasive cichlids do have a negative relationship with the native sunfish. Many of these native sunfish are also important sportfish, such as large mouth bass and bluegill. Due to the fact that larval, juvenile and adult life stages were collected during this study, these invasive cichlids are indeed reproducing.

Invasive fish species do occur in coastal tributaries in Texas and are spreading into more waterways. Previous studies conducted by TPWD found invasive fish in larger bayous above our sampling sites, such as Green's and Bray's Bayous and more recent TPWD studies on Dickinson Bayou support this (Robinson & Culbertson, 2005, Culbertson, pers. comm.). Based on previous research (Robinson & Culbertson, 2005; Culbertson pers. comm.; TCEQ, 1990-2002; Denton pers. comm.; Kelly,2000, Guillen, pers. comm., Martin, 2000; Guillen, 1992; Oborny, 1997, and Parsons, 2003) invasive cichlids are also spreading throughout the Galveston Bay system. According to this previous data, the first recorded occurrence of the Rio Grande cichlid was in 1990 and the first recorded occurrence of Tilapia was in 1996. Based on the previous research and this study it seems appropriate to consider a range extension for *Cichlasoma cyanoguttatum*, originally native to the Rio Grande watershed in Texas, but now it is in the Clear Lake, Texas watershed, as well.

There is a need for continued research on invasive fish species within the Clear Lake and Galveston Bay watersheds. Long term and seasonal studies could tell us more about how and when the invasive fish are affecting the native fish community. The Loricariid catfish may be less susceptible to the gear used in this study therefore; future studies may need to include gill nets or other gear in addition to seines and electroshocking equipment, in order to capture these organisms. Controlled laboratory studies should also be conducted to determine how cichlids affect centrarchids growth. Age-growth studies should also be undertaken to determine how old these invasive fish are, and if they are growing at faster rates in these altered streams compared to average growth in other systems. In addition, monitoring of the smaller, wadeable tributaries and bayous on a regular basis by state resource agencies (e.g. TPWD and/or TCEQ) is necessary in order to determine the spread of invasive species and ultimately in being able to control nonnative fish invasions.

Prevention is the key to stopping invasive species from spreading into new areas (Dextrase & Mandrak, 2006). It is important to educate the public on the invasive fish and their detrimental effects on the environment. Also, people should be aware of what to do if they find an invasive fish so they do not release it back into the watershed. Pet stores and aquarium shops should also be more proactive in informing customers about how to properly dispose of unwanted fish, for example shop owners could allow anyone to bring in unwanted live fish and then dispose of the fish for them if they are unable to be sold.

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Appendix I:

Animal Care Protocol

Application (4,05)

GENERAL STATEMENT ON THE USE OF ANIMALS

We believe that the use of living animals in properly designed research experiments is both ethical and obligatory to protect people and animals from diseases and defects. All animals used in our research are acquired from proper sources in compliance with local, state, and federal laws and guidelines and are housed and cared for in accordance with all appropriate laws and guidelines.

While at the University, the animals are provided with the best possible care and treatment and are under the care of a veterinarian trained in Laboratory Animal Medicine.

Our experimental protocols and program for animal care and use have been reviewed and approved by the University's Institutional Animal Care and Use Committee. We subscribe and adhere to the concept and practice of the humane treatment of research animals, using only the minimum numbers necessary to answer the research questions. Special care is always taken in all behavioral and surgical procedures to avoid any pain or discomfort to the animals. Also, all animals are cared for and handled with respect.

Application (4,05)

PROTOCOL NO. 05.00X

ADMINISTRATIVE INFORMATION SHEET

NOTE: DO NOT SHOW ANY PERSONNEL NAMES OR ROOM NUMBERS ON THE FORM ENTITLED "APPLICATION FOR USE OF LABORATORY ANIMALS AND FACILITIES"

(1) Principal Investigator/Instructor George Guillen Phone Number281-283-3950 Fax 281-283-3953

Email Guillen@uhcl.edu Emergency Contact Number 281-218-0327

Department / Campus address 2700 Bay Area Blvd, Box 540

(2) Animals will be used for Instruction X Research

a. If used for instruction: Course No

b. If used for research: Sponsoring Agency(ies) UHCL, EIH,

UH Budget No.(s), if any

If proposal(s), List titles(s) and submission deadline(s)

(3) Show the name(s) and extension(s) of each person (including the PI) working with the animals. Indicate the date(s) of the most recent training session for each individual. Titles should describe project assignment and not necessarily academic appointment.

NAME AND TITLE	PHONE NUMBER	TRAINING DATE	ADD	DELETE
George Guillen, Assoc. Professor	281-283-3950	7-21-05	☒	☐

Biology

Dianna Ramirez, graduate student	281-283-3950	5-31-06	☒	☐
______	______	______	☐	☐
______	______	______	☐	☐
______	______	______	☐	☐
______	______	______	☐	☐

(4) Preferred location for animal housing: ☐ S&R2 ☐ Optometry ☐ Pharmacy/TMC ☒ Clear Lake

(5) Location where animal use will take place: Either off campus collections and/or Room Bayou 3214

(6) Animals kept over 12 hours outside housing area? ☐ YES X NO
If yes, give location and reason.

(7) If animals will be housed any place other than in animal care facilities during or following exposure to a hazardous agent, note the Location:

*I certify that the use of all animals involved in this project will be carried out within the provisions of the Animal Welfare Act, the Guide for Care and Use of Laboratory Animals, the PHS Policy on Humane Care and Use of Animals, the University of Houston Policy on Care and Use of Animals and related animal welfare rules and regulations as issued by state and/or federal agencies.
*I am aware that the Institutional Animal Care and Use Committee (IACUC) may make periodic inspections of all labs in which animals are used. I will permit unannounced inspections and observations of our animals and surgical techniques by a UH veterinarian or other representative of the IACUC.
*I am aware that the IACUC is empowered to stop any objectionable procedure or project. Where procedures have caused severe distress to an animal, which cannot be alleviated, UH staff veterinarians are authorized to humanely euthanize that animal. I understand that every attempt will be made to contact me before any action is taken.
*I certify that the above statements are true and that I will make written notification to the IACUC of any changes in the proposed project prior to proceeding with any animal experiment.
*I understand that I cannot start this project until I have received approval from the IACUC.

_____ _____
SIGNATURE of Principal Investigator or Instructor DATE
("Per" signature not accepted)

Application (4,05)

PROTOCOL NO. **05.00X**

UNIVERSITY OF HOUSTON
APPLICATION FOR USE OF LABORATORY ANIMALS AND FACILITIES
ANIMAL USE PROTOCOL REVIEW

This form is to be completed IN FULL FOR ALL research projects and/or teaching activities using vertebrate animals, regardless of whether or not I am a UH faculty member, the source of funds or location where animals are to be housed. For assistance in completing this form contact the Institutional Animal Care and Use Committee (ACO) Office, Ext. 39199. The decision of the Institutional Animal Care and Use Committee will be sent to the investigator in writing.

INSTRUCTIONS: SUBMIT THE TYPED ORIGINAL AND 12 COPIES along with any necessary documentation (i.e., appropriate sections of grant proposal, class/laboratory procedures, etc.) to the Animal Care Operations (ACO) office, Room 10 SR II. The animal use protocol is reviewed by the Director, Animal Care Operations and is reviewed and approved by the Institutional Animal Care and Use Committee in fulfillment of requirements of the Animal Welfare Act. Therefore, this application form must be filled out completely to assure expeditious review by the Committee. THE ACO OFFICE MUST BE NOTIFIED OF ANY CHANGES IN THE APPROVED PROTOCOL BEFORE THEY ARE INITIATED. If separate sheets of paper are used, items and answers must be clearly labeled. Once approved, all protocols must be renewed at least annually. To prevent delay in the review process all questions must be answered.

(1) Project Title: THE RELATIONSHIP BETWEEN ENVIRONMENTAL CHARACTERISTICS AND INVASIVE FISH SPECIES IN SELECTED BAYOUS WITHIN THE LOWER GALVESTON BAY WATERSHED DURING SUMMER MONTHS.

(2) Investigator's Lay Summary of the Project. THIS IS RESTRICTED TO 100-150 WORDS and should include the

following: (a) hypothesis; (b) Total number and types of animals to be used over what period of time; (c) significance of the project. THIS SUMMARY SHOULD BE WRITTEN IN LAY LANGUAGE AND BE APPROPRIATE FOR RELEASE TO THE NEWS MEDIA.

The main goal of our study is to determine which environmental conditions have a significant relationship on the composition of exotic invasive fishes and overall fish communities in selected smaller, wadeable bayous and streams within the lower Galveston Bay-watershed. At least five to ten stations, located within two to four tributaries of lower Galveston Bay, will be compared during 2006 and 2007. These include tributaries and mainstem sites of the Clear Creek, Dickinson Bayou, Canal B, Highland Bayou, and Armand Bayou watersheds. Due to extensive residential development the area, certain watersheds are believed to be undergoing extensive degradation of both physical habitat and water quality. For example, Armand Bayou is less developed and provides a regional control watershed. Since both are tributaries of Clear Lake, they should experience similar meteorological conditions and similar risks of exposure to invasive species. The first objective of our study will be to examine the relationship between water quality and invasive fish species. Our null hypothesis is that invasive fish species are found in equivalent numbers in degraded and minimally impacted streams. Degradation will be determined by the measurement of selected water and habitat variables. This second objective of our study will also examine the relationship between invasive fish and native fish by comparing invasive fish abundance and size with native fish abundance. Our null hypothesis is that native fish communities are similar in areas with and without invasive fish species. Fish community metrics that will be compared include overall fish community composition, overall native and invasive fish abundance, numbers of fish taxa, Shannon's species diversity (H') and Pielou's evenness (E) and numbers and abundance of native sunfish species.

This research project will incorporate the collection of fish in the field for taxonomic identification and population assessment. Sampling methods will include the collection of fish using large nets, plankton nets, traps, gillnets, and electrofishing gear (Murphy and Willis 1996; Fisheries Techniques). In general, I expect that on the average fewer than 250 fish per species will be collected at each station over an annual period. For >70% of the species sampled, less than 30 specimens will be collected. Approximately 95% of the individuals of each species collected will be euthanized for the study. These fish will be sacrificed with MS222 immediately. The remaining fish (5%) will be released back into the water body unharmed. The long-range objective of our study is to develop a predictive habitat/fish model useful for management and control of invasive fish species, fisheries resources and physical/water quality.

(3) List 3-5 keywords

Fish, field sampling, preservation, population

(4) Husbandry Requirements: If anything other than routine care and equipment is required, note below. If more than one species is to be used, indicate which will require special husbandry. Your selection(s) must be justified.

- ☐ Wire bottom cages;
- ☐ Individual housing;
- ☐ Special diet;
- ☐ Metabolism cages;
- ☐ Treated water;
- ☐ Unique lighting;
- ☐ Filter tops;
- ☐ Autoclaved feed, bedding and cages;
- ☒ Other (Please explain)

Fish will be collected in the field and in some cases sacrificed for later identification in the laboratory.

(5) Environmental Enrichment and Exercise: This is required by the Animal Welfare Act. Non-human primates must be given opportunities to exercise and enjoy environmental enrichment (games, various toys, different fruits, foods). If this will impact adversely on your research to the point that it will ruin the experiment, you must justify your claim.

Not applicable. Fish are the sole vertebrate being used. Most fish will be dead prior to arriving at the lab.

(6) Dogs must receive exercise if housed singly, depending on the size of the enclosure, or be housed in compatible groups as part of their care. If this will impact adversely on your research to the point that it will interfere with your study, you must justify the non-exercise aspect.

Not applicable. Fish are the sole vertebrate being used. Most fish will be dead prior to arriving at the lab.

(7) Rationale: State the overall rationale and significance of this project.

The collection and identification of fish is a necessary component of our research study. Our research will focus on the quantification of habitat and water quality needs of invasive and native estuarine and freshwater fishes. Currently, we are investigating the relative role that habitat and water quality plays in the structuring of native and exotic fish populations that inhabit freshwater and estuarine ecosystems. Fish communities, water quality and habitat will be sampled in streams, marshes, and bayous to determine the relationship of diversity, population parameters, and these variables. The techniques that I will be using are common methods used by academic and government scientists engaged in marine and aquatic ecological and fisheries research. In most cases, due to the small size and/or taxonomic diversity of fish there is a need to utilize taxonomic keys that emphasize meristic (e.g. fin ray counts, morphological measurements, etc.) internal and external characters. Therefore, confidently identifying sampled species will require sacrificing representative specimens.

Application (4,05)

(8) Animal Model(s): Complete the following, listing each species, strain, stock or breed separately. If you plan to use more than one species/strain you must supply this information for each species/strain. (Use the next application page for more than one animal model.)

Species: Strain, Stock or Breed:

Source: Age and/or Size:

Sex: ☐ MALE ☐ FEMALE;

Number of animals housed per day:	High: 0	Average: 0
Number of days each animal will be housed:	High: 0	Average: 0

Maximum number of animals required YR1 YR2 YR3 TOTAL

(9) Will the protocol call for any of the following?

	YES	NO
a. Use of muscle-paralyzing drugs without anesthesia	☐	☒
b. Long-term (4 hours or longer) restraint (chemical and/or physical)	☐	☒
c. Creation or maintenance of a painful or uncomfortable condition	☐	☒
d. Feed and/or water deprivation	☐	☒

If yes to any of the above you must explain and justify.

(10) Does the protocol prohibit the use of anesthetics and/or analgesics for the conduct of painful procedures? ☐YES ☒ NO

If yes, explain and justify below. Attach documentation when available. Note: Painful procedures are considered to be those which cause more pain than that associated with routine injections or blood withdrawal. Foot pad injections and cardiac punctures are painful.

Application (4,05)

(11) The Animal Welfare Act requires that each registered animal facility submit an annual report on animal usage. In addition to total numbers of animals used, the report must identify numbers of animals used in various categories relating to pain or distress. To make it possible for this report to be filed, please provide the following information. Give either actual numbers of animals or the percentage of animals to be used in each category (please indicate whether your answer is in actual numbers or percentage). Provide information for each species of animal named in this animal use request. (Use the next additional application page NO. 11 if more than one species).

Species	Number or percent of animals used in research experiments, tests, or teaching involving no pain distress. (N)	Number or percent of animals used in research experiments, tests, or teaching where appropriate or anesthetic, analgesic, or tranquilizer drugs will be administered to avoid pain or distress. (D)	Number or percent of animals used in research experiments, tests, or teaching involving pain or distress without administration of appropriate anesthetic, analgesic, or tranquilizer drugs. (P)
FISH (various species)	**5%(**Minimum percentage of fish collected in the net which are released back into the environment (larger specimens easy to i.d.)	**95%** (Maximum percentage of living fish collected in the net which are euthanized with MS-222 prior to fixation)	0%

If a number or percentage is in the last column, Appendix "A" must be completed. It must accompany the annual USDA report (APHIS FORM 7023)

(12) Restraint: Will physical restraint devices be used? ☒ YES ☐ NO
If yes, describe the type of restraint and indicate the frequency and length of time the animal will be restrained. Provision must be made for exercise within the 12 hour period if animals are restrained longer than 12 hours

Fish will be collected using seines, backpack electroshockers, gillnets, plankton nets, and trawls. To reduce stress and discomfort to minimum levels, I will keep fish restrained only for a minimum (< 5-10 minutes) time period in either a portable aerated tank or bucket. Once captured fish will be either euthanatized with high doses of MS-222 (for smaller fish), an ice water bath, or a sharp blow to the head (some larger fish), for subsequent preservation in formalin. Whenever possible large fishes will be immediately identified, measured, and released immediately back into the waterbody to reduce stress and avoid death.

(13) Alternative Methods: If alternative models (other than vertebrate animals) exist, explain the reason for not using these models. If no alternatives exist, please furnish a brief explanation. "No alternatives" is not an acceptable explanation. The database (AGRICOLA) of the National Agriculture Library **must** be searched for alternative methodology.

Fish population analysis requires the evaluation of fish populations and vital statistics. This requires the collection of fish density data, growth information estimated from bony structures and length data, and spawning as estimated from gonad developmental stage, and overall condition (weight and length data). There are no other animal models in ecology that can substitute for this group, since we are trying to evaluate local endemic population trends.

Application (4,05)

Databases Searched AGRICOLA

Search Period Covered < 2006

DATES SEARCHED: 7-22-05 & 5-4-06

Key Words Used: Fish Model Systems

Results of search. Short synopsis of results of search(es).

Our research is not duplicative of other programs within the University of Houston, or hosted by other Universities within our area. Our research will involve the comprehensive evaluation of fish populations in freshwater, estuarine and coastal waters. The proposed research will compare and evaluate the spatial and vertical zonation of fish populations in the Gulf coast freshwater and marine systems. This research has been identified by NMFS, TCEQ, EPA, and Sea Grant as a primary research need in recent request of proposals and white papers and the Galveston Bay Plan.

No pertinent articles returned. 9 articles dealing with various specific computer models or toxicology retrieved. None applied to our research application.

Title: Intermediate filament cytoskeleton / edited by M. Bishr Omary, Pierre A. Coulombe.

Title: Quality of fresh and processed foods / edited by Fereidoon Shahidi ... [et al.]

Title: International aquatic animal health code : fish, molluscs and crustaceans.

Title: Melatonin after four decades : an assessment of its potential / edited by James Olcese.

Title: Process-induced chemical changes in food / edited by Title: Satistics for the environment / edited by Vic Barnett and K. Feridun Turkman.

Title: The legal-institutional analysis model (LIAM): a validation study / by Leah J. Wilds.

Title: A new perspective in institutional analysis : the Legal-Institutional Analysis Model (LIAM) / by Leah J.Wilds.

Title: A dynamic linear programming model of fish culture in water reuse systems / by J.M. Gates, C.R. MacDonald, B.J. Pollard.

Title: Chitosan as an edible invisible film for quality preservation of herring and Atlantic cod. Jeon, Y.J.

Title: Oxidative deterioration in dried fish model systems assessed by solid sample fluorescence spectrophotometry. Hasegawa, K.

(14) Duplication of Research: A statement as to whether the instruction/research being conducted is/is not duplicative of other instruction/research as revealed by a detailed perusal of the literature. If duplication of instruction/research efforts is indicated, a statement of justification is required.

These procedures will include the actual netting and landing of fish prior to sacrificing. Fish will be euthanized, with ice packs, trauma to the head or lethal dose of MS-222. Afterwards specimens will be placed in formalin for long-term preservation and/or removal of bony structures for ageing.

(15) Describe the procedures that will be followed in detail. For non-surgical animal procedures list all invasive procedures and potentially stressful non-invasive procedures. (Examples: IM injections, foot pad injections, venapuncture, cardiac

Non-invasive procedures

punctures, behavioral training.) Note each species if more than one species is included. For all surgical procedures indicate whether or not the animal will survive the surgery (i.e. is the surgery to be acute), methods used to insure sterility of survival surgery in vertebrates the anesthetic agent(s) and doses and routes used, the anticipated post-operative survival time, post-operative care (including required analgesic(s) and their doses), whether or not survival surgery will be performed more than once on a single animal and who should be contacted in case of emergency. (If necessary, continue on one additional page. If more than one page is needed, please justify this need.)

Application (4,05)

(16) Data Analysis plan: Include the proposed calculations and statistical procedures to be used and how the numbers of animals to be used were determined

Animal sacrificed in the field will be used to estimate various population parameters including density, mortality, growth, and age. Density will be obtained from counting the number of organisms collected by unit area or volume. Mortality, growth and age data will be obtained from a variety of methods including, reductions in catch per unit effort (CPUE) over various age groups, length or weight frequency analysis (e.g., statistical mixture analysis), analysis of otolith (ear bones) and scale growth rings (ear bones), and examination of RNA/DNA ratios. These statistical methods are outlined in various fisheries population analysis texts including Pauly (1984), Hilborn and Walters (1991), and Quinn (1998). Due to the nature of ecological research it is difficult to project absolute numbers of fish used, but will likely run less than 1000 individuals per species during any annual period. In the majority (95%) of cases, this number will be less than 25 individuals per species.

(17) Indicate the qualifications of the person(s) - who will perform/monitor each procedure, including invasive procedures, such as the administration of anesthesia. Each position should show either enrollment in or completion of the UH Animal course; or comparable experience. List experience with each species and procedures to be used. Where associates lack experience with the experimental methods and/or procedures proposed, a statement detailing the strict supervision of the individual must be included.

The principal investigator and instructor George Guillen has over 21 years experience as a practicing fisheries biologist and has been trained in all methods of fish handling and euthanasia. Dr. Guillen is an AFS Certified Fisheries Scientist. Dr. Guillen has previous experience directing fishery projects, which involved similar procedures including invasive and non-invasive procedures. He worked for TPWD for 4 years, TCEQ for 12 years, MMS for 2 years and FWS for 4 years. Dr. Guillen has completed the UH Animal Care Course. Dr. Guillen has also received advanced training in fish tagging methods at the University of California - Davis and has taught several courses on the investigation of fish kills for USFWS and others. Dr. Guillen has over 20 publications on fish ecology and marine biology. Ms. Diana Ramirez is his graduate student. Ms. Ramirez has a B.S. in Marine Biology from Texas A&M University at Galveston and has had previous training in Field Ichthyology and identification of aquatic organisms. Before approval of this protocol (or no later than May 31, 2006), Ms. Ramirez will have completed the UH Animal Care Course.

(18) Tissue/fluid collection: Will you be extracting any tissues/fluids (i.e. blood, urine, bile) from the animals that are to survive? ☐ YES ☒ NO

If yes, provide the following information, (Use an additional page NO.18 if more than one fluid is to be collected)

Type of tissues/fluid: Amount extracted/collected:

Frequency of collection: Total amount collected:

Method of Collection:

(19) Drug or reagent administration: Will you be administering drugs, reagents including adjuvants or dry substance other than the anesthetics or analgesics described previously to these animals? ☐ YES ☒ NO
If yes, provide the following for each substance. (Use additional application page if necessary.)

(a) Substance:
Dose:
Route:
Frequency:

Post administration complications:

(b) Is agent hazardous (e.g. radioisotope, chemical carcinogen or viable microbiological agent)? ☐ YES ☐ NO

(c) If yes, is animal expected to survive exposure? ☐ YES ☐ NO

(d) Dates(s) of the appropriate safety committee approval(s). NOTE: IACUC approval will not be issued until these approvals are obtained.

Check those that apply and indicate date of approval:
- ☐ Biohazards Date
- ☐ Radiation safety Date
- ☐ Chemical / Carcinogen Safety Date
- ☐ Recombinant DNA Date

(e) Degree of health hazard to humans (mark "X" for the most appropriate number).

Low		Moderate		High
☐	☐	☐	☐	☐
1	2	3	4	5

(f) Length of time that animals and/or their environment must be considered hazardous:

Not applicable.

(19) Continued

(g) Maximum number of exposed animals that will be maintained at any one time:

0

(h) What decontamination procedures will be required for equipment, personnel and housing areas?

Not applicable.

(i) How will contaminated animals, feed, bedding and disposable supplies be handled?

Not applicable.

(j) If an infectious agent is involved, specify therapy for the treatment of infected animals or humans, as well as preventative measures available for each.

Not applicable.

(20) Euthanasia: List method(s) of euthanasia to be used for each species.

The following methods will be used to euthanize fish. For small fishes they will be immersed in a bath of water either containing high doses (0.06%) of MS-222 or ice water, and held for 5-10 minutes or until they stop respiratory movements, followed by preservation in formalin. Larger fish will be euthanized by a quick blow to the head prior to preservation. Fish that have already died in the net or prior to attempts to euthanize them will be directly placed in 7% formalin. Larval fish may be placed directly in liquid nitrogen for evaluation of RNA/DNA ratios due to the potential for degradation of nucleic acids and invalidation of experimental protocol.

APPENDIX II:

Water Quality and Physical Characteristics Summary Tables:

Table II-1: Water quality per site per sampling period. Parameters that were collected more than once per sampling were averaged.

Site	Date	pH	Cond. (µS)	Alkalinity (mg/L CaCO3)	Ammonia (mg/L NH4)	Temp. (°C)	Salinity (psu)	Phosphate (mg/L PO4)	Nitrate (mg/L NO3-N)	Turbidity (average) (ntu)	Secci (average) (cm)	Dissolved Oxygen (average) (mg/L)
ABFAIR	10-Jun-06	7.70	460	192	0.50	28.0	0.0	0.75	0.02	15.38	51.10	4.13
ABFAIR	16-Jul-06	8.80	425	132	0.40	34.2	0.0	1.15	0.02	7.85	65.93	10.33
ABFAIR	12-Aug-06	7.70	380	140	0.40	30.0	0.0	1.41	0.04	7.82	66.27	5.07
ABFAIR	03-Sep-06	7.70	410	122	0.40	29.0	0.0	1.17	0.01	6.29	68.40	5.07
ABHB	28-Jun-06	7.10	500	160	0.40	31.0	0.0	0.21	0.02	8.23	32.87	7.93
ABHB	29-Jul-06	7.30	300	120	0.25	27.6	0.0	0.50	0.01	15.17	35.47	3.87
ABHB	19-Aug-06	7.30	660	176	0.10	29.0	0.0	2.98	0.02	16.50	39.07	4.00
ABHB	09-Sep-06	7.50	550	204	0.40	26.0	0.0	0.54	0.01	5.65	80.40	1.33
CHIGG	23-Jun-06	7.50	720	200	0.70	31.0	0.0	1.19	0.00	5.91	76.13	1.90
CHIGG	24-Jul-06	7.40	400	174	0.10	29.0	0.0	0.93	0.00	6.50	70.07	2.67
CHIGG	20-Aug-06	7.10	420	104	0.80	28.0	0.0	3.12	0.00	21.03	39.20	2.97
CHIGG	17-Sep-06	7.60	6590	172	0.20	29.5	6.0	0.19	0.01	3.71	97.40	5.23
COW	24-Jun-06	7.30	760	144	0.30	29.0	0.0	2.75	0.00	27.47	21.67	6.83
COW	28-Jul-06	6.60	590	124	0.10	28.0	0.0	2.75	0.00	21.40	18.87	2.40
COW	26-Aug-06	7.30	2270	196	0.50	29.0	6.0	1.26	0.07	18.68	15.53	4.13
COW	23-Sep-06	7.70	1690	165	0.20	28.0	2.0	2.01	0.01	13.53	34.73	3.07
HPBF	06-Jun-06	7.50	920	276	0.30	26.8	0.0	2.75	0.00	4.25	114.00	2.81
HPBF	07-Jul-06	7.50	400	200	0.60	27.0	0.0	0.72	0.04	8.22	89.07	4.33
HPBF	13-Aug-06	7.30	730	240	0.60	27.0	0.0	2.58	0.01	4.68	97.53	2.97
HPBF	16-Sep-06	7.70	780	264	0.20	28.0	0.0	0.43	0.02	8.54	54.07	2.73
HPSC	22-Jun-06	7.50	740	144	0.50	30.0	0.0	1.09	0.38	11.10	38.47	5.10
HPSC	15-Jul-06	7.70	850	156	0.20	26.7	0.0	2.56	0.55	7.86	71.43	5.33
HPSC	12-Aug-06	7.30	1550	148	0.00	29.0	3.0	7.88	8.32	3.72	85.50	5.53
HPSC	03-Sep-06	7.50	1590	185	0.30	27.0	0.0	7.68	0.47	6.77	40.00	5.37
MAG	17-Jun-06	7.50	830	234	0.40	27.6	0.0	1.28	0.00	7.58	55.60	3.57
MAG	30-Jul-06	7.40	530	172	0.10	29.0	6.0	2.75	0.00	24.20	26.97	4.73
MAG	31-Aug-06	7.10	440	152	0.60	26.0	0.0	0.74	0.00	17.25	28.27	5.37
MAG	06-Oct-06	7.20	1000	266	0.50	24.5	0.0	0.20	0.15	5.74	56.33	4.80
MARY	27-Jun-06	8.50	800	220	0.40	28.0	0.0	2.75	0.13	49.30	12.33	6.97
MARY	28-Jul-06	8.30	380	160	0.00	31.0	0.0	2.75	0.03	37.90	16.33	6.93
MARY	26-Aug-06	8.90	930	232	0.30	31.0	0.0	4.82	0.42	20.10	19.87	11.60
MARY	23-Sep-06	9.30	930	240	0.50	28.0	2.0	6.96	0.14	49.10	10.80	11.60
BAP	24-Jun-06	8.25	125000	*	*	31.1	5.0	1.92	0.05	36.40	28.00	9.00
BAP	22-Jul-06	8.85	1000	128	*	32.2	9.0	0.92	0.04	366.67	12.80	12.30
BAP	30-Aug-06	8.60	1290	160	0.50	30.0	10.0	1.80	0.05	37.37	16.60	7.10
BAP	22-Sep-06	8.70	10750	168	0.50	28.0	10.0	2.66	0.02	18.61	18.47	7.40

* No data available

Table II-2: Physical characteristics per site per sampling period. Parameters that were collected more than once per sampling were averaged.

Site	Date	Wentworth (average)	% submerged vegetation (average)	% emergent vegetation (average)	% concrete/boulders (average)	% soft sediment (average)	Stream Depth (average)(ft)	velocity (average) (ft/sec)	Stream bank slope (average)(°)	Stream Width (average) (ft)	Flow (ft^3/sec)	Habitat Complexity	pool %	riffle %	run %
ABFAIR	10-Jun-06	2.33	0.00	0.00	0.00	100.00	0.87	0.07	90.00	10.23	0.000	0.843	60	20	20
ABFAIR	16-Jul-06	1.94	0.33	0.50	0.00	100.00	0.68	0.00	70.00	11.57	0.000	0.632	30	10	60
ABFAIR	12-Aug-06	1.17	0.00	0.00	0.00	100.00	0.88	0.12	83.33	11.73	0.000	0.667	20	20	60
ABFAIR	03-Sep-06	0.72	0.00	0.00	0.00	100.00	0.93	0.00	80.00	10.67	0.000	0.816	30	30	40
ABHB	28-Jun-06	1.17	0.00	0.00	30.00	70.00	1.33	0.00	58.33	11.00	0.000	0.699	50	10	40
ABHB	29-Jul-06	0.94	16.67	5.00	38.33	61.67	2.33	0.56	52.50	12.13	9.185	0.789	40	20	40
ABHB	19-Aug-06	1.94	0.00	25.00	30.00	70.00	1.37	0.14	35.00	10.67	0.000	0.823	50	20	30
ABHB	09-Sep-06	1.00	0.00	0.00	0.00	100.00	1.05	0.00	80.00	7.87	0.000	0.632	30	10	60
CHIGG	23-Jun-06	0.22	0.00	5.00	0.00	100.00	1.73	0.00	75.83	11.33	0.000	0.516	60	40	0
CHIGG	24-Jul-06	0.39	0.33	3.00	0.33	100.00	2.03	0.20	75.83	11.95	0.000	0.483	30	0	70
CHIGG	20-Aug-06	0.28	0.00	5.50	0.00	100.00	2.87	0.69	43.33	12.87	14.156	0.675	40	10	50
CHIGG	17-Sep-06	1.11	58.33	20.50	0.00	100.00	1.07	0.00	64.17	10.67	0.000	0.316	10	0	90
COW	24-Jun-06	0.00	0.00	3.00	0.00	100.00	2.10	0.06	28.33	16.23	0.000	0.000	0	0	100
COW	28-Jul-06	0.00	0.00	10.00	0.00	100.00	3.30	1.04	14.17	16.30	45.715	0.000	0	0	100
COW	26-Aug-06	0.00	0.00	3.00	0.00	100.00	2.02	0.00	38.33	15.07	0.000	0.000	0	0	100
COW	23-Sep-06	0.00	0.00	12.50	0.00	100.00	1.97	0.00	50.83	14.90	0.000	0.000	0	0	100
HPBF	06-Jun-06	1.50	65.00	25.00	0.00	75.00	0.75	0.12	80.00	12.27	0.021	0.516	40	0	60
HPBF	07-Jul-06	0.56	16.67	0.00	0.00	100.00	0.93	0.00	73.33	11.52	0.000	0.675	40	10	50
HPBF	13-Aug-06	0.00	26.67	20.00	0.00	100.00	0.90	0.00	70.00	8.33	0.000	0.316	10	0	90
HPBF	16-Sep-06	0.50	0.00	3.00	0.00	100.00	1.67	0.00	81.67	12.26	0.000	0.422	20	0	80
HPSC	22-Jun-06	0.33	0.00	2.50	0.00	100.00	2.30	0.17	65.00	18.37	5.041	0.483	30	0	70
HPSC	15-Jul-06	0.44	0.00	0.00	0.00	100.00	1.27	0.48	46.67	10.57	4.473	0.000	0	0	100
HPSC	12-Aug-06	0.33	0.00	0.50	0.00	100.00	1.78	0.12	37.50	16.10	3.965	0.422	20	0	80
HPSC	03-Sep-06	0.00	90.00	0.50	0.00	100.00	2.83	0.00	75.83	16.58	0.000	0.422	20	0	80
MAG	17-Jun-06	1.11	58.33	0.00	5.00	36.67	1.13	0.24	65.83	9.90	0.338	0.675	40	10	50
MAG	30-Jul-06	1.33	83.33	0.00	13.33	86.67	1.57	0.36	70.00	8.80	2.170	0.568	20	10	70
MAG	31-Aug-06	0.56	30.00	0.50	0.00	100.00	1.53	0.84	52.50	8.53	3.108	0.632	30	10	60
MAG	06-Oct-06	0.22	3.67	0.00	0.00	100.00	0.92	0.27	60.00	8.55	0.715	0.516	40	0	60
MARY	27-Jun-06	0.00	30.00	25.00	0.00	100.00	1.60	0.11	26.00	31.77	0.000	0.000	0	0	100
MARY	28-Jul-06	0.00	0.00	17.50	0.00	100.00	3.00	0.65	29.17	38.63	62.579	0.000	0	0	100
MARY	26-Aug-06	0.00	20.00	0.00	0.00	100.00	1.20	0.00	18.33	26.67	0.000	0.000	0	0	100
MARY	23-Sep-06	0.00	1.00	45.00	0.00	100.00	1.17	0.51	30.83	25.60	3.851	0.000	0	0	100
BAP	24-Jun-06	*	*	*	*	100.00	*	*	*	*	*	*	*	*	*
BAP	22-Jul-06	*	*	*	*	100.00	*	*	*	*	*	*	*	*	*
BAP	30-Aug-06	*	*	*	*	100.00	*	*	*	*	*	*	*	*	*
BAP	22-Sep-06	*	*	*	*	100.00	*	*	*	*	*	*	*	*	*

*no data available

a. Cond. = Conductivity, temp. = temperature

APPENDIX III:

Water Quality Raw Data:

Table III-1: Raw data for water quality parameters.

DATE	site	pH	Cond	alkalinity	ammonia	air_temp	water_tem	salinity	pctcloud	rain	last_rain	wind_spee	wind_direc	water_colo	phosphate	nitrate	Turb_up	turb_mid	turb_dwn	secci_up	secci_mid	secci_dwn
June102006	ABFAIR_1	7.7	460	192	0.5	29.8	28	0	0	no				unknown	0.75	0.02	15.4	21.6	9.14	35.9	65.2	52.2
July162006	ABFAIR_2	8.8	425	132	0.4	34.5	34.2	0	50	no				yell/brwn	1.15	0.02	7.3	7.52	8.72	60.4	72.6	64.8
Aug122006	ABFAIR_3	7.7	380	140	0.4	34	30	0	70	no	2			brwn	1.41	0.04	7.37	6.1	9.99	63	62.8	73
Sep32006	ABFAIR_4	7.7	410	122	0.4	32.5	29	0	30	no				yellow/grn	1.17	0.01	5.25	6.99	6.62	69	61.8	74.4
June282006	ABHB_1	7.1	500	160	0.4	33	31	0	25	no					0.21	0.02	12.5	3.5	8.7	41.8	18.8	38
July292006	ABHB_2	7.3	300	120	0.25	30	27.6	0	10	no	2			brwn	0.5	0.01	13.8	16.6	15.1	40	23	43.4
Aug192006	ABHB_3	7.3	660	176	0.1	28.5	29	0	100	yes	0			brwn	2.98	0.02	31.3	9.95	8.24	20.8	37.2	59.2
Sep92006	ABHB_4	7.5	550	204	0.4	23.5	26	0	100	yes	0	5		yell/brwn	0.54	0.01	5.86	5.55	5.54	71.6	80	89.6
June232006	CHIGG_1	7.5	720	200	0.7	37	31	0	50	no					1.19	0	6.02	6.17	5.55	50.6	67.8	110
July242006	CHIGG_2	7.4	400	174	0.1	28	29	0	90	no	0			dkbrwn	0.93	0	5.77	7.85	5.89	78	59.8	72.4
Aug202006	CHIGG_3	7.1	420	104	0.8	30	28	0	0	no				dkbrwn	3.12	0	19.9	22.4	20.8	40.2	45.2	32.2
Sep172006	CHIGG_4	7.6	6590	172	0.2	32	29.5	6	50	yes	0	5		yellow	0.19	0.01	2.78	4.26	4.09	111.3	89.7	91.2
June242006	COW_1	7.3	760	144	0.3	31	29	0	50	no					2.75	0	19.5	18.8	44.1	25.3	27.4	12.3
July282006	COW_2	6.6	590	124	0.1	29	28	0	20	no	1	5	SE	brwn	2.75	0	19.3	22.7	22.2	17.2	20.3	19.1
Aug262006	COW_3	7.3	2270	196	0.5	33.5	29	6	40	yes	0	5	NW	brwn	1.26	0.07	25.8	17.76	12.48	21.4	15	10.2
Sep232006	COW_4	7.7	1690	165	0.2	30	28	2	50	no				brwn	2.01	0.01	12.7	15.21	12.67	33.6	33.4	37.2
June062006	HPBF_1	7.5	920	276	0.3	26.5	26.8	0	99	yes	0			unknown	2.75	0	2.79	5.67	4.29	120	102	120
July72006	HPBF_2	7.5	400	200	0.6	26.5	27	0	100	no	0			unknown	0.72	0.04	8.35	8.35	7.95	103	77.8	86.4
Aug132006	HPBF_3	7.3	730	240	0.6	29	27	0	0	no	3	5		yellow/brwı	2.58	0.01	3.31	4.93	5.79	105	120	67.6
Sep162006	HPBF_4	7.7	780	264	0.2	29	28	0	75	yes	0	5		yellow/brwı	0.43	0.02	5.13	10.2	10.28	63.8	44.4	54.0
June222006	HPSC_1	7.5	740	144	0.5	37	30	0	60	no	1			unknown	1.09	0.38	12.31	11.1	9.9	46.2	26.6	42.6
July152006	HPSC_2	7.7	850	156	0.2	25.1	26.7	0	1	no				yellow	2.56	0.55	8.01	9.37	6.2	72	66	76.3
Aug122006	HPSC_3	7.3	1550	148	0	30	29	3	10	no	2	5		brwn/grn	7.88	8.32	3.5	2.62	5.03	91.6	92.3	72.6
Sep32006	HPSC_4	7.5	1590	185	0.3	26	27	0	0	no		5		brwn	7.68	0.47	5.95	6.55	7.8	52.4	33.4	34.2
June172006	MAG_1	7.5	830	234	0.4	29.9	27.6	0	75	yes	0				1.28	0.00	5.3	13.25	4.19	89.9	42.0	34.9
July302006	MAG_2	7.4	530	172	0.1	27.6	29.0	6	50	no	3			brown	2.75	0.00	19.4	29.6	23.6	26.3	27.2	27.4
Aug312006	MAG_3	7.1	440	152	0.6	28.0	26.0	0	0	no	3	5		yellow/brwı	0.74	0.00	14.13	19.48	18.14	32.2	32.4	20.2
Oct62006	MAG_4	7.2	1000	266	0.5	26.0	24.5	0	0	no		5		yellow/brwı	0.20	0.15	4.85	6.86	5.51	59.6	57.4	52.0
June272006	MARY_1	8.5	800	220	0.4	30	28	0	5	no					2.75	0.13	36.5	68.9	42.5	15.6	6	15.4
July282006	MARY_2	8.3	380	160	0	32	31	0	50	no	1			brwn	2.75	0.03	38.8	38.3	36.6	18	14.8	16.2
Aug262006	MARY_3	8.9	930	232	0.3	31	31	0	100	yes	0			yellow	4.82	0.42	24	16.1	20.2	18.2	16.2	25.2
Sep232006	MARY_4	9.3	930	240	0.5	32	28	2	75	yes	0			grn	6.96	0.14	48	50	49.3	11.8	10.6	10
June242006	BAP_1	8.25	125000			33.3	31.1	5							1.92	0.05	36.4	n/a	n/a	28		
July222006	BAP_2	8.85	1000	128	<1ppm	32.8	32.2	9	35			<5	SE	green	0.92	0.04	364	359	377	12.8		
Aug302006	BAP_3	8.6	1290	160	0.5	28.5	30	10	50	no	2	<5		grnbrwn	1.8	0.05	33	36.9	42.2	17.6	16.4	15.8
Sep222006	BAP_4	8.7	10750	168	0.5	30	28	10	1	no			S	ylwbrwn	2.66	0.02	16.15	16.47	23.2	18.2	19.2	18

APPENDIX V

Biological Raw Data:

See attached CD with electronic data

APPENDIX VI

Fish Length Data:

Fish Length Statistics:
ES Overall Descriptive Statistics: SL (mm)

Variable	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	792	26.009	0.671	18.873	11.000	20.000	220.000	209.000

ES Station/Date/Type Descriptive Statistics: SL (mm)
Descriptive Statistics: SL (mm)

Results for Station = ABFair, Date = 6/10/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	C	3	94.0	13.3	23.1	72.0	92.0	118.0	46.0
	N	21	33.33	9.54	43.73	15.00	20.00	220.00	205.00

Results for Station = ABFair, Date = 7/16/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	N	36	23.64	1.17	7.00	14.00	21.00	53.00	39.00

Results for Station = ABFair, Date = 8/12/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	C	4	79.25	9.41	18.82	62.00	74.50	106.00	44.00
	N	13	30.00	3.58	12.90	17.00	26.00	60.00	43.00

Results for Station = ABFair, Date = 9/3/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	C	2	107.00	8.00	11.31	99.00	107.00	115.00	16.00
	N	10	32.10	6.91	21.86	15.00	24.00	88.00	73.00

Results for Station = ABHB, Date = 6/28/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	N	32	22.52	1.07	6.08	13.00	21.00	37.00	24.00

Results for Station = ABHB, Date = 9/9/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum
SL (mm)	C	1	68.000	*	*	68.000	68.000	68.000
	I	1	17.000	*	*	17.000	17.000	17.000
	N	29	24.72	3.07	16.54	13.00	20.00	82.00

Variable	Type	Range
SL (mm)	C	0.000000
	I	0.000000
	N	69.00

Results for Station = ABHB, Date = *

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	N	1	27.000	*	*	27.000	27.000	27.000	0.000000

Results for Station = Chigger, Date = 6/23/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	N	51	21.451	0.906	6.469	13.000	20.000	46.000	33.000

Results for Station = Chigger, Date = 7/24/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	C	8	16.312	0.432	1.223	14.000	16.500	18.000	4.000
	I	3	26.00	2.08	3.61	23.00	25.00	30.00	7.00
	N	60	21.767	0.818	6.339	13.000	21.000	55.000	42.000

Results for Station = Cowards, Date = 6/24/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	2	24.00	6.00	8.49	18.00	24.00	30.00	12.00
	N	52	19.346	0.731	5.273	14.000	18.000	49.000	35.000

Results for Station = HPBF, Date = 6/16/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	6	41.8	15.7	38.4	16.0	19.0	106.0	90.0
	N	37	20.446	0.669	4.072	15.000	19.000	30.000	15.000

Results for Station = HPBF, Date = 7/7/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	3	24.67	9.21	15.95	14.00	17.00	43.00	29.00
	N	27	19.259	0.782	4.063	13.000	19.000	33.000	20.000

Results for Station = HPBF, Date = 8/13/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	7	16.86	2.43	6.44	13.00	14.00	31.00	18.00
	N	32	16.250	0.460	2.603	12.000	16.500	21.000	9.000

Results for Station = HPBF, Date = 9/16/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	29	14.638	0.385	2.074	11.000	14.000	19.000	8.000
	N	34	17.721	0.650	3.790	11.000	17.000	27.000	16.000

Results for Station = HPSC, Date = 6/22/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum
SL (mm)	C	1	31.000	*	*	31.000	31.000	31.000
	N	45	19.633	0.598	4.009	13.500	19.000	30.000

Variable	Type	Range
SL (mm)	C	0.000000
	N	16.500

Results for Station = Magnolia, Date = 6/17/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	C	25	67.40	2.84	14.20	43.00	69.00	90.00	47.00
	N	67	35.12	3.38	27.70	14.00	26.00	146.00	132.00

Results for Station = Magnolia, Date = 7/30/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	N	37	27.53	1.41	8.60	18.00	26.00	62.00	44.00

Results for Station = Magnolia, Date = 8/31/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum
SL (mm)	C	4	53.50	9.49	18.98	29.00	58.00	69.00
	I	1	39.000	*	*	39.000	39.000	39.000
	N	26	38.27	6.34	32.30	17.00	26.00	153.40

Variable	Type	Range
SL (mm)	C	40.00
	I	0.000000
	N	136.40

Results for Station = Mary's, Date = 6/27/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	N	32	20.469	0.637	3.605	16.000	20.000	32.000	16.000

Results for Station = Mary's, Date = 9/23/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	N	50	23.430	0.905	6.399	11.000	22.000	40.000	29.000

ES Correlations: Mean Centrarchid, Mean Invasive

Pearson correlation of Mean Centrarchid and Mean Invasive = 0.599
P-Value = 0.117

Seine Data

Descriptive Statistics: SL (mm)

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum
SL (mm)	I	1540	23.993	0.499	19.564	4.000	17.000	170.000
	N	545	46.59	1.22	28.46	11.00	41.00	195.00

Variable	Type	Range
SL (mm)	I	166.000
	N	184.00

Descriptive Statistics: SL (mm)

Results for Station = ABFair, Date = 6/10/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	N	16	72.75	6.24	24.94	36.00	73.50	116.00	80.00

Results for Station = ABFair, Date = 7/16/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum
SL (mm)	I	1	25.000	*	*	25.000	25.000	25.000
	N	14	71.00	7.12	25.66	31.00	68.00	123.00

Variable	Type	Range
SL (mm)	I	0.000000
	N	92.00

Results for Station = ABFair, Date = 8/12/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	5	45.4	15.7	35.1	10.0	35.0	84.0	74.0
	N	20	57.73	3.69	16.52	36.00	60.00	96.00	60.00

Results for Station = ABFair, Date = 9/3/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	12	58.7	10.5	36.5	13.0	79.5	97.0	84.0
	N	20	64.15	5.65	25.26	22.00	60.50	141.00	119.00

Results for Station = ABHB, Date = 6/28/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	91	13.09	1.26	12.00	6.10	10.30	90.00	83.90
	N	20	57.42	5.70	25.51	23.00	55.00	115.00	92.00

Results for Station = ABHB, Date = 7/29/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	20	59.00	1.62	7.25	44.00	60.00	69.00	25.00
	N	7	72.14	8.62	22.80	36.00	70.00	103.00	67.00

Results for Station = ABHB, Date = 8/19/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	24	67.71	4.96	24.30	15.00	74.50	105.00	90.00
	N	16	69.47	9.07	36.29	15.50	72.50	130.00	114.50

Results for Station = ABHB, Date = 9/9/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	30	24.25	4.07	22.27	12.00	16.00	87.00	75.00
	N	7	43.57	9.05	23.95	13.00	32.00	75.00	62.00

Results for Station = BAP, Date = 6/24/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	6	23.33	2.40	5.89	19.00	21.50	35.00	16.00
	N	4	31.5	10.8	21.6	12.0	30.0	54.0	42.0

Results for Station = BAP, Date = 7/22/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum
SL (mm)	N	2	15.000	0.000000	0.000000	15.000	15.000	15.000

Variable	Type	Range
SL (mm)	N	0.000000

Results for Station = BAP, Date = 8/30/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	8	16.88	4.22	11.94	10.00	12.75	46.00	36.00
	N	3	51.5	17.3	30.0	32.0	36.5	86.0	54.0

Results for Station = BAP, Date = 9/22/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	2	58.5	41.5	58.7	17.0	58.5	100.0	83.0
	N	2	87.5	43.5	61.5	44.0	87.5	131.0	87.0

Results for Station = BAP, Date = 8/30/2008

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	1	11.000	*	*	11.000	11.000	11.000	0.000000

Results for Station = Chigger, Date = 6/23/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	43	29.83	4.76	31.19	11.00	19.00	170.00	159.00
	N	55	32.75	2.86	21.23	13.00	22.00	79.00	66.00

Results for Station = Chigger, Date = 7/24/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	5	62.0	25.2	56.3	18.0	48.0	155.0	137.0
	N	10	42.30	9.08	28.70	17.00	34.00	103.00	86.00

Results for Station = Chigger, Date = 8/30/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	29	19.86	3.86	20.80	10.00	13.00	114.00	104.00
	N	15	38.70	7.04	27.26	16.00	25.00	101.00	85.00

Results for Station = Chigger, Date = 9/17/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum
SL (mm)	I	198	19.576	0.771	10.850	11.000	18.000	145.000
	N	63	26.93	2.36	18.72	12.00	18.00	111.00

Variable	Type	Range
SL (mm)	I	134.000
	N	99.00

Results for Station = Coward's, Date = 6/24/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	32	32.97	1.66	9.38	18.00	31.00	67.00	49.00
	N	7	27.86	9.26	24.49	11.00	21.00	80.00	69.00

Results for Station = Coward's, Date = 7/28/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	N	1	99.000	*	*	99.000	99.000	99.000	0.000000

Results for Station = Coward's, Date = 8/26/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	87	33.08	2.71	25.24	9.00	18.00	140.00	131.00
	N	17	43.12	5.84	24.07	18.00	33.00	119.00	101.00

Results for Station = Coward's, Date = 9/23/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	138	29.50	1.47	17.21	12.00	24.00	102.00	90.00

	N	7	35.43	9.77	25.85	14.00	32.00	89.00	75.00

Results for Station = HPBF, Date = 6/16/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum
SL (mm)	I	275	15.651	0.871	14.447	4.000	9.000	77.000
	N	4	47.8	16.9	33.9	14.0	44.0	89.0

Variable	Type	Range
SL (mm)	I	73.000
	N	75.0

Results for Station = HPBF, Date = 7/7/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	16	41.56	5.97	23.88	10.00	38.50	84.00	74.00

Results for Station = HPBF, Date = 8/13/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum
SL (mm)	I	237	15.932	0.369	5.681	9.100	14.100	54.000
	N	1	19.000	*	*	19.000	19.000	19.000

Variable	Type	Range
SL (mm)	I	44.900
	N	0.000000

Results for Station = HPBF, Date = 9/16/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	42	23.20	1.93	12.48	12.00	18.00	60.00	48.00
	N	7	15.857	0.595	1.574	14.000	15.000	18.000	4.000

Results for Station = HPSC, Date = 6/22/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum
SL (mm)	I	1	11.000	*	*	11.000	11.000	11.000
	N	9	63.7	13.3	39.8	15.0	61.0	155.0

Variable	Type	Range
SL (mm)	I	0.000000
	N	140.0

Results for Station = HPSC, Date = 7/15/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	N	1	82.000	*	*	82.000	82.000	82.000	0.000000

Results for Station = HPSC, Date = 8/12/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	6	19.75	2.06	5.04	16.00	17.25	28.00	12.00

Results for Station = HPSC, Date = 9/3/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum
SL (mm)	I	7	15.857	0.585	1.547	14.000	16.000	18.000
	N	1	14.000	*	*	14.000	14.000	14.000

Variable	Type	Range

Variable	Type	Range
SL (mm)	I	4.000
	N	0.000000

Results for Station = Magnolia, Date = 6/17/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	15	39.04	2.40	9.29	26.20	38.00	55.00	28.80
	N	29	73.95	6.63	35.69	21.00	67.00	195.00	174.00

Results for Station = Magnolia, Date = 7/30/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	4	70.3	17.9	35.8	17.0	84.5	95.0	78.0
	N	3	103.3	36.8	63.7	53.0	82.0	175.0	122.0

Results for Station = Magnolia, Date = 8/31/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum
SL (mm)	I	7	64.00	8.07	21.36	33.00	73.00	87.00
	N	1	61.000	*	*	61.000	61.000	61.000

Variable	Type	Range
SL (mm)	I	54.00
	N	0.000000

Results for Station = Magnolia, Date = 10/6/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	4	79.9	14.9	29.9	35.5	93.0	98.0	62.5
	N	19	62.53	6.00	26.16	14.00	70.00	102.00	88.00

Results for Station = Mary's, Date = 6/27/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	10	25.05	5.18	16.38	10.00	19.50	69.00	59.00
	N	59	35.61	2.66	20.40	12.00	26.00	110.00	98.00

Results for Station = Mary's, Date = 7/28/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	84	20.304	0.822	7.538	10.000	18.000	48.000	38.000
	N	56	40.32	2.50	18.73	11.00	32.00	77.00	66.00

Results for Station = Mary's, Date = 8/26/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	69	35.95	2.09	17.38	13.00	31.00	82.00	69.00
	N	26	47.19	3.43	17.47	24.00	41.00	90.00	66.00

Results for Station = Mary's, Date = 9/23/2006

Variable	Type	Total Count	Mean	SE Mean	StDev	Minimum	Median	Maximum	Range
SL (mm)	I	31	25.39	1.84	10.25	13.00	26.00	52.00	39.00
	N	23	52.43	3.30	15.84	15.00	52.00	76.00	61.00

APPENDIX VII:

Statistics reports: ANOVA

Seine data ANOVA GLM

Welcome to Minitab, press F1 for help.
Retrieving project from file: 'E:\RESEAR~1\STATS\SEINE DATA ALL.MPJ'

Results for: Worksheet 7

General Linear Model: Cichlids versus station_1, Month

Factor	Type	Levels	Values
station_1	fixed	8	ABFair, ABHB, Chigger, Coward's, HPBF, HPSC, Mag, Marys
Month	fixed	4	1, 2, 3, 4

Analysis of Variance for Cichlids, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
station_1	7	6021.9	6021.9	860.3	8.43	0.000
Month	3	1035.4	1035.4	345.1	3.38	0.019
station_1*Month	21	8261.9	8261.9	393.4	3.85	0.000
Error	288	29406.3	29406.3	102.1		
Total	319	44725.5				

S = 10.1047   R-Sq = 34.25%   R-Sq(adj) = 27.17%

General Linear Model: Went versus site, month

Factor	Type	Levels	Values
site	fixed	8	ABFAIR, ABHB, CHIGG, COW, HPBF, HPSC, MAG, MARY
month	fixed	4	1, 2, 3, 4

Analysis of Variance for Went, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
site	7	79.149	79.149	11.307	9.48	0.000
month	3	6.476	6.476	2.159	1.81	0.146
site*month	21	36.899	36.899	1.757	1.47	0.086
Error	256	305.222	305.222	1.192		
Total	287	427.747				

S = 1.09191   R-Sq = 28.64%   R-Sq(adj) = 20.00%

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Went
All Pairwise Comparisons among Levels of site
site = ABFAIR subtracted from:

```
site    Lower  Center    Upper  ---------+---------+---------+-------
ABHB   -1.058  -0.278   0.5029            (------*-----)
CHIGG  -1.822  -1.042  -0.2609      (-----*------)
COW    -2.322  -1.542  -0.7609  (-----*------)
HPBF   -1.683  -0.903  -0.1221       (-----*------)
HPSC   -2.045  -1.264  -0.4832    (-----*------)
MAG    -1.517  -0.736   0.0446        (------*-----)
MARY   -2.322  -1.542  -0.7609  (-----*------)
                                ---------+---------+---------+-------
                                      -1.2       0.0       1.2


site = ABHB  subtracted from:

site    Lower  Center    Upper  ---------+---------+---------+-------
CHIGG  -1.545  -0.764   0.0168        (------*-----)
COW    -2.045  -1.264  -0.4832    (-----*------)
HPBF   -1.406  -0.625   0.1557         (------*-----)
HPSC   -1.767  -0.986  -0.2054      (------*-----)
MAG    -1.239  -0.458   0.3224           (-----*------)
MARY   -2.045  -1.264  -0.4832    (-----*------)
                                ---------+---------+---------+-------
                                      -1.2       0.0       1.2


site = CHIGG  subtracted from:

site   Lower   Center   Upper  ---------+---------+---------+-------
COW   -1.281  -0.5000  0.2807          (------*-----)
HPBF  -0.642   0.1389  0.9196                (-----*------)
HPSC  -1.003  -0.2222  0.5585             (-----*------)
MAG   -0.475   0.3056  1.0863                 (------*-----)
MARY  -1.281  -0.5000  0.2807          (------*-----)
                               ---------+---------+---------+-------
                                     -1.2       0.0       1.2


site = COW  subtracted from:

site    Lower    Center   Upper  ---------+---------+---------+-------
HPBF  -0.1418  0.638889  1.4196                    (-----*------)
HPSC  -0.5029  0.277778  1.0585                 (-----*------)
MAG    0.0248  0.805556  1.5863                     (------*-----)
MARY  -0.7807  0.000000  0.7807              (------*------)
                                 ---------+---------+---------+-------
                                       -1.2       0.0       1.2


site = HPBF  subtracted from:

site   Lower   Center   Upper  ---------+---------+---------+-------
HPSC  -1.142  -0.3611  0.4196           (------*-----)
MAG   -0.614   0.1667  0.9474                (-----*------)
MARY  -1.420  -0.6389  0.1418         (------*-----)
                               ---------+---------+---------+-------
                                     -1.2       0.0       1.2


site = HPSC  subtracted from:

site   Lower   Center   Upper  ---------+---------+---------+-------
MAG   -0.253   0.5278  1.3085                   (-----*------)
MARY  -1.058  -0.2778  0.5029            (------*-----)
```

```
                                 ---------+---------+---------+-------
                                       -1.2       0.0       1.2


site = MAG  subtracted from:

site   Lower   Center     Upper  ---------+---------+---------+-------
MARY  -1.586  -0.8056  -0.02484        (-----*------)
                                 ---------+---------+---------+-------
                                       -1.2       0.0       1.2
```

General Linear Model: subveg versus site, month

```
Factor  Type   Levels  Values
site    fixed       8  ABFAIR, ABHB, CHIGG, COW, HPBF, HPSC, MAG, MARY
month   fixed       4  1, 2, 3, 4


Analysis of Variance for subveg, using Adjusted SS for Tests

Source      DF   Seq SS   Adj SS  Adj MS     F      P
site         7  19205.2  19205.2  2743.6  9.02  0.000
month        3   1493.1   1493.1   497.7  1.64  0.190
site*month  21  44502.0  44502.0  2119.1  6.97  0.000
Error       64  19462.0  19462.0   304.1
Total       95  84662.2


S = 17.4383   R-Sq = 77.01%   R-Sq(adj) = 65.88%


Tukey 95.0% Simultaneous Confidence Intervals
Response Variable subveg
All Pairwise Comparisons among Levels of site
site = ABFAIR  subtracted from:

site    Lower   Center  Upper  -----+---------+---------+---------+-
ABHB   -18.22   4.0833  26.38            (-----*------)
CHIGG   -7.72  14.5833  36.88               (-----*------)
COW    -22.38  -0.0833  22.22           (-----*-----)
HPBF     4.70  27.0000  49.30                  (------*-----)
HPSC     0.12  22.4167  44.72                 (-----*------)
MAG     21.45  43.7500  66.05                       (------*-----)
MARY    -9.63  12.6667  34.97              (------*-----)
                               -----+---------+---------+---------+-
                                  -35         0        35        70


site = ABHB  subtracted from:

site    Lower  Center  Upper  -----+---------+---------+---------+-
CHIGG  -11.80  10.500  32.80             (-----*-----)
COW    -26.47  -4.167  18.13        (------*-----)
HPBF     0.62  22.917  45.22                (------*-----)
HPSC    -3.97  18.333  40.63               (-----*------)
MAG     17.37  39.667  61.97                     (-----*------)
MARY   -13.72   8.583  30.88           (-----*------)
                              -----+---------+---------+---------+-
                                 -35         0        35        70


site = CHIGG  subtracted from:
```

```
site   Lower  Center   Upper  -----+---------+---------+---------+-
COW   -36.97  -14.67   7.634      (------*-----)
HPBF   -9.88   12.42  34.717              (------*-----)
HPSC  -14.47    7.83  30.134             (-----*------)
MAG     6.87   29.17  51.467                   (-----*------)
MARY  -24.22   -1.92  20.384          (-----*------)
                              -----+---------+---------+---------+-
                                 -35         0        35        70


site = COW  subtracted from:

site   Lower  Center  Upper  -----+---------+---------+---------+-
HPBF   4.783   27.08  49.38                 (------*-----)
HPSC   0.199   22.50  44.80                (-----*------)
MAG   21.533   43.83  66.13                      (------*-----)
MARY  -9.551   12.75  35.05             (------*-----)
                             -----+---------+---------+---------+-
                                -35         0        35        70


site = HPBF  subtracted from:

site   Lower  Center   Upper  -----+---------+---------+---------+-
HPSC  -26.88   -4.58  17.717         (------*-----)
MAG    -5.55   16.75  39.051               (------*-----)
MARY  -36.63  -14.33   7.967       (-----*-----)
                              -----+---------+---------+---------+-
                                 -35         0        35        70


site = HPSC  subtracted from:

site   Lower  Center  Upper  -----+---------+---------+---------+-
MAG    -0.97  21.333  43.63                (-----*-----)
MARY  -32.05  -9.750  12.55        (-----*------)
                             -----+---------+---------+---------+-
                                -35         0        35        70


site = MAG  subtracted from:

site   Lower  Center   Upper  -----+---------+---------+---------+-
MARY  -53.38  -31.08  -8.783  (-----*-----)
                              -----+---------+---------+---------+-
                                 -35         0        35        70
```

General Linear Model: secchi versus site, month

```
Factor  Type   Levels  Values
site    fixed       8  ABFAIR, ABHB, CHIGG, COW, HPBF, HPSC, MAG, MARY
month   fixed       4  1, 2, 3, 4


Analysis of Variance for secci, using Adjusted SS for Tests

Source      DF   Seq SS   Adj SS  Adj MS      F      P
site         7  50649.2  50649.2  7235.6  47.72  0.000
month        3    626.7    626.7   208.9   1.38  0.258
site*month  21  23554.2  23554.2  1121.6   7.40  0.000
Error       64   9704.5   9704.5   151.6
```

```
Total       95  84534.6


S = 12.3140   R-Sq = 88.52%   R-Sq(adj) = 82.96%


Tukey 95.0% Simultaneous Confidence Intervals
Response Variable secci
All Pairwise Comparisons among Levels of site
site = ABFAIR  subtracted from:

site    Lower  Center   Upper  --------+---------+---------+--------
ABHB   -31.72  -15.97   -0.23              (--*--)
CHIGG   -7.97    7.77   23.52                  (---*--)
COW    -55.97  -40.22  -24.48         (--*--)
HPBF     9.99   25.74   41.49                      (--*--)
HPSC   -19.82   -4.07   11.67                (--*--)
MAG    -36.88  -21.13   -5.39             (--*--)
MARY   -63.84  -48.09  -32.34       (--*---)
                               --------+---------+---------+--------
                                     -50         0        50


site = ABHB  subtracted from:

site    Lower  Center   Upper  --------+---------+---------+--------
CHIGG    8.00   23.75   39.50                      (--*--)
COW    -40.00  -24.25   -8.50            (--*--)
HPBF    25.97   41.72   57.46                         (--*--)
HPSC    -3.85   11.90   27.65                   (--*---)
MAG    -20.91   -5.16   10.59                (--*--)
MARY   -47.86  -32.12  -16.37          (---*--)
                               --------+---------+---------+--------
                                     -50         0        50


site = CHIGG  subtracted from:

site   Lower  Center   Upper  --------+---------+---------+--------
COW   -63.75  -48.00  -32.25       (--*---)
HPBF    2.22   17.97   33.71                    (---*--)
HPSC  -27.60  -11.85    3.90              (---*--)
MAG   -44.66  -28.91  -13.16           (--*--)
MARY  -71.61  -55.87  -40.12      (--*--)
                              --------+---------+---------+--------
                                    -50         0        50


site = COW  subtracted from:

site   Lower  Center   Upper  --------+---------+---------+--------
HPBF   50.22  65.967  81.714                            (--*--)
HPSC   20.40  36.150  51.897                      (--*--)
MAG     3.34  19.092  34.839                   (--*--)
MARY  -23.61  -7.867   7.881             (--*---)
                              --------+---------+---------+--------
                                    -50         0        50


site = HPBF  subtracted from:

site   Lower  Center   Upper  --------+---------+---------+--------
HPSC  -45.56  -29.82  -14.07           (--*--)
```

```
MAG   -62.62  -46.87  -31.13       (---*--)
MARY  -89.58  -73.83  -58.09  (--*--)
                              --------+---------+---------+--------
                                    -50         0        50


site = HPSC  subtracted from:

site   Lower  Center   Upper  --------+---------+---------+--------
MAG   -32.81  -17.06   -1.31              (---*--)
MARY  -59.76  -44.02  -28.27        (--*--)
                              --------+---------+---------+--------
                                    -50         0        50


site = MAG  subtracted from:

site   Lower  Center   Upper  --------+---------+---------+--------
MARY  -42.71  -26.96  -11.21            (---*--)
                              --------+---------+---------+--------
                                    -50         0        50
```

General Linear Model: Bankslope versus site, month

```
Factor  Type   Levels  Values
site    fixed       8  ABFAIR, ABHB, CHIGG, COW, HPBF, HPSC, MAG, MARY
month   fixed       4  1, 2, 3, 4


Analysis of Variance for Bnkslp, using Adjusted SS for Tests

Source       DF    Seq SS    Adj SS  Adj MS      F      P
site          7   61483.9   61483.9  8783.4  13.02  0.000
month         3    9201.5    9201.5  3067.2   4.55  0.004
site*month   21   14374.3   14374.3   684.5   1.01  0.449
Error       160  107920.0  107920.0   674.5
Total       191  192979.7


S = 25.9711   R-Sq = 44.08%   R-Sq(adj) = 33.24%


Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Bnkslp
All Pairwise Comparisons among Levels of site
site = ABFAIR  subtracted from:

site    Lower  Center   Upper  ---------+---------+---------+-------
ABHB   -47.38  -24.37   -1.37         (-----*-----)
CHIGG  -39.05  -16.04    6.97           (-----*-----)
COW    -70.92  -47.92  -24.91   (-----*-----)
HPBF   -27.59   -4.58   18.42              (-----*-----)
HPSC   -47.59  -24.58   -1.58         (-----*-----)
MAG    -41.76  -18.75    4.26           (----*-----)
MARY   -77.76  -54.75  -31.74  (----*-----)
                               ---------+---------+---------+-------
                                      -40         0        40


site = ABHB  subtracted from:

site    Lower  Center   Upper  ---------+---------+---------+-------
```

```
CHIGG  -14.67    8.33  31.341                 (-----*-----)
COW    -46.55  -23.54  -0.534         (-----*-----)
HPBF    -3.22   19.79  42.799                    (-----*-----)
HPSC   -23.22   -0.21  22.799               (-----*-----)
MAG    -17.38    5.62  28.633                 (----*-----)
MARY   -53.38  -30.37  -7.367        (----*-----)
                                ---------+---------+---------+-------
                                       -40         0        40
```

```
site = CHIGG  subtracted from:

site   Lower  Center   Upper  ---------+---------+---------+-------
COW   -54.88  -31.88   -8.87       (-----*-----)
HPBF  -11.55   11.46   34.47                  (-----*-----)
HPSC  -31.55   -8.54   14.47             (-----*-----)
MAG   -25.72   -2.71   20.30               (----*-----)
MARY  -61.72  -38.71  -15.70      (----*-----)
                              ---------+---------+---------+-------
                                     -40         0        40
```

```
site = COW  subtracted from:

site   Lower  Center  Upper  ---------+---------+---------+-------
HPBF   20.33  43.333  66.34                        (-----*-----)
HPSC    0.33  23.333  46.34                   (-----*-----)
MAG     6.16  29.167  52.17                     (----*-----)
MARY  -29.84  -6.833  16.17             (----*-----)
                             ---------+---------+---------+-------
                                    -40         0        40
```

```
site = HPBF  subtracted from:

site   Lower  Center   Upper  ---------+---------+---------+-------
HPSC  -43.01  -20.00    3.01          (-----*-----)
MAG   -37.17  -14.17    8.84            (----*-----)
MARY  -73.17  -50.17  -27.16   (----*-----)
                              ---------+---------+---------+-------
                                     -40         0        40
```

```
site = HPSC  subtracted from:

site   Lower  Center   Upper  ---------+---------+---------+-------
MAG   -17.17    5.83  28.841                (----*-----)
MARY  -53.17  -30.17  -7.159       (----*-----)
                              ---------+---------+---------+-------
                                     -40         0        40
```

```
site = MAG  subtracted from:

site   Lower  Center   Upper  ---------+---------+---------+-------
MARY  -59.01  -36.00  -12.99      (-----*-----)
                              ---------+---------+---------+-------
                                     -40         0        40
```

General Linear Model: CENTRAR versus station_1, Month

```
Factor     Type   Levels  Values
```

```
station_1  fixed       8  ABFair, ABHB, Chigger, Coward's, HPBF, HPSC, Mag,
                          Marys
Month      fixed       4  1, 2, 3, 4


Analysis of Variance for CENTRAR, using Adjusted SS for Tests

Source            DF    Seq SS    Adj SS   Adj MS      F      P
station_1          7   719.022   719.022  102.717  16.94  0.000
Month              3   134.009   134.009   44.670   7.37  0.000
station_1*Month   21   410.966   410.966   19.570   3.23  0.000
Error            288  1746.500  1746.500    6.064
Total            319  3010.497


S = 2.46257   R-Sq = 41.99%   R-Sq(adj) = 35.74%


Tukey 95.0% Simultaneous Confidence Intervals
Response Variable CENTRAR
All Pairwise Comparisons among Levels of station_1
station_1 = ABFair  subtracted from:

station_1   Lower  Center   Upper  -----+---------+---------+---------+-
ABHB       -2.220  -0.550  1.1204           (---*----)
Chigger     0.430   2.100  3.7704                  (----*----)
Coward's   -2.645  -0.975  0.6954         (----*----)
HPBF       -3.145  -1.475  0.1954        (----*----)
HPSC       -3.170  -1.500  0.1704        (----*---)
Mag        -2.245  -0.575  1.0954           (---*----)
Marys       1.080   2.750  4.4204                    (----*----)
                                   -----+---------+---------+---------+-
                                     -3.5       0.0       3.5       7.0


station_1 = ABHB  subtracted from:

station_1   Lower   Center   Upper  -----+---------+---------+---------+-
Chigger     0.980   2.6500  4.3204                    (----*---)
Coward's   -2.095  -0.4250  1.2454           (----*----)
HPBF       -2.595  -0.9250  0.7454          (---*----)
HPSC       -2.620  -0.9500  0.7204          (---*----)
Mag        -1.695  -0.0250  1.6454            (----*----)
Marys       1.630   3.3000  4.9704                      (---*----)
                                    -----+---------+---------+---------+-
                                      -3.5       0.0       3.5       7.0


station_1 = Chigger  subtracted from:

station_1   Lower  Center   Upper  -----+---------+---------+---------+-
Coward's   -4.745  -3.075  -1.405   (----*----)
HPBF       -5.245  -3.575  -1.905  (----*----)
HPSC       -5.270  -3.600  -1.930  (----*---)
Mag        -4.345  -2.675  -1.005     (---*----)
Marys      -1.020   0.650   2.320            (----*----)
                                   -----+---------+---------+---------+-
                                     -3.5       0.0       3.5       7.0


station_1 = Coward's  subtracted from:

station_1   Lower   Center  Upper  -----+---------+---------+---------+-
```

```
HPBF       -2.170  -0.5000  1.170          (----*---)
HPSC       -2.195  -0.5250  1.145          (---*----)
Mag        -1.270   0.4000  2.070            (----*----)
Marys       2.055   3.7250  5.395                      (----*---)
                                  -----+---------+---------+---------+-
                                    -3.5       0.0       3.5       7.0


station_1 = HPBF  subtracted from:

station_1   Lower    Center  Upper  -----+---------+---------+---------+-
HPSC       -1.695  -0.02500  1.645           (----*----)
Mag        -0.770   0.90000  2.570              (----*---)
Marys       2.555   4.22500  5.895                       (----*----)
                                    -----+---------+---------+---------+-
                                      -3.5       0.0       3.5       7.0


station_1 = HPSC  subtracted from:

station_1    Lower  Center  Upper  -----+---------+---------+---------+-
Mag        -0.7454  0.9250  2.595             (----*---)
Marys       2.5796  4.2500  5.920                      (----*----)
                                   -----+---------+---------+---------+-
                                     -3.5       0.0       3.5       7.0


station_1 = Mag  subtracted from:

station_1  Lower  Center  Upper  -----+---------+---------+---------+-
Marys      1.655   3.325  4.995                    (----*---)
                                 -----+---------+---------+---------+-
                                   -3.5       0.0       3.5       7.0
```

General Linear Model: Cichlids versus station_1, Month

```
Factor     Type   Levels  Values
station_1  fixed       8  ABFair, ABHB, Chigger, Coward's, HPBF, HPSC, Mag,
                          Marys
Month      fixed       4  1, 2, 3, 4


Analysis of Variance for Cichlids, using Adjusted SS for Tests

Source            DF   Seq SS   Adj SS  Adj MS     F      P
station_1          7   6021.9   6021.9   860.3  8.43  0.000
Month              3   1035.4   1035.4   345.1  3.38  0.019
station_1*Month   21   8261.9   8261.9   393.4  3.85  0.000
Error            288  29406.3  29406.3   102.1
Total            319  44725.5


S = 10.1047   R-Sq = 34.25%   R-Sq(adj) = 27.17%


Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Cichlids
All Pairwise Comparisons among Levels of station_1
station_1 = ABFair  subtracted from:

station_1   Lower   Center   Upper  -------+---------+---------+---------
```

```
ABHB        -3.204   3.6500  10.504                (-----*-----)
Chigger     -0.404   6.4500  13.304                   (----*-----)
Coward's    -0.879   5.9750  12.829                  (-----*-----)
HPBF         6.871  13.7250  20.579                         (----*-----)
HPSC        -6.954  -0.1000   6.754             (-----*-----)
Mag         -6.554   0.3000   7.154              (----*-----)
Marys       -2.429   4.4250  11.279                 (-----*----)
                                    -------+---------+---------+---------
                                         -12         0        12


station_1 = ABHB  subtracted from:

station_1   Lower  Center   Upper  -------+---------+---------+---------
Chigger     -4.05   2.800   9.654               (----*-----)
Coward's    -4.53   2.325   9.179              (-----*-----)
HPBF         3.22  10.075  16.929                    (----*-----)
HPSC       -10.60  -3.750   3.104          (-----*-----)
Mag        -10.20  -3.350   3.504          (-----*-----)
Marys       -6.08   0.775   7.629              (-----*----)
                                   -------+---------+---------+---------
                                        -12         0        12


station_1 = Chigger  subtracted from:

station_1   Lower  Center    Upper  -------+---------+---------+---------
Coward's    -7.33  -0.475   6.3791             (-----*----)
HPBF         0.42   7.275  14.1291                   (-----*-----)
HPSC       -13.40  -6.550   0.3041       (-----*----)
Mag        -13.00  -6.150   0.7041       (-----*-----)
Marys       -8.88  -2.025   4.8291            (----*-----)
                                    -------+---------+---------+---------
                                         -12         0        12


station_1 = Coward's  subtracted from:

station_1   Lower  Center    Upper  -------+---------+---------+---------
HPBF         0.90   7.750  14.6041                    (----*-----)
HPSC       -12.93  -6.075   0.7791       (-----*-----)
Mag        -12.53  -5.675   1.1791        (----*-----)
Marys       -8.40  -1.550   5.3041            (-----*----)
                                    -------+---------+---------+---------
                                         -12         0        12


station_1 = HPBF  subtracted from:

station_1   Lower  Center   Upper  -------+---------+---------+---------
HPSC       -20.68  -13.82  -6.971  (----*-----)
Mag        -20.28  -13.42  -6.571  (-----*-----)
Marys      -16.15   -9.30  -2.446      (----*-----)
                                   -------+---------+---------+---------
                                        -12         0        12


station_1 = HPSC  subtracted from:

station_1   Lower  Center   Upper  -------+---------+---------+---------
Mag        -6.454  0.4000   7.254              (----*-----)
Marys      -2.329  4.5250  11.379                 (-----*----)
                                   -------+---------+---------+---------
```

```
                                              -12         0        12
```

```
station_1 = Mag  subtracted from:

station_1   Lower  Center  Upper  -------+---------+---------+---------
Marys      -2.729   4.125  10.98                  (----*-----)
                                  -------+---------+---------+---------
                                      -12         0        12
```

General Linear Model: Shannon-Wiener versus station_1, Month

```
Factor     Type   Levels  Values
station_1  fixed       8  ABFair, ABHB, Chigger, Coward's, HPBF, HPSC, Mag,
                          Marys
Month      fixed       4  1, 2, 3, 4


Analysis of Variance for Shannon-Wiener, using Adjusted SS for Tests

Source            DF   Seq SS   Adj SS  Adj MS      F      P
station_1          7   8.8909   8.8909  1.2701  11.37  0.000
Month              3   0.6657   0.6657  0.2219   1.99  0.116
station_1*Month   21   7.2057   7.2057  0.3431   3.07  0.000
Error            288  32.1659  32.1659  0.1117
Total            319  48.9282


S = 0.334196   R-Sq = 34.26%   R-Sq(adj) = 27.18%

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Shannon-Wiener
All Pairwise Comparisons among Levels of station_1
station_1 = ABFair  subtracted from:

station_1    Lower   Center   Upper  ---------+---------+---------+-------
ABHB       -0.0722   0.1545  0.3812                 (-----*-----)
Chigger     0.1923   0.4190  0.6457                        (----*-----)
Coward's    0.0106   0.2373  0.4640                   (-----*-----)
HPBF       -0.2873  -0.0606  0.1661            (----*-----)
HPSC       -0.3420  -0.1153  0.1114          (-----*-----)
Mag         0.0187   0.2454  0.4721                   (-----*-----)
Marys      -0.0919   0.1348  0.3615                 (----*-----)
                                     ---------+---------+---------+-------
                                          -0.40      0.00      0.40


station_1 = ABHB  subtracted from:

station_1    Lower   Center     Upper  ---------+---------+---------+-------
Chigger     0.0378   0.2645   0.49117                      (-----*----)
Coward's   -0.1439   0.0828   0.30951                 (-----*-----)
HPBF       -0.4418  -0.2151   0.01161          (-----*----)
HPSC       -0.4965  -0.2698  -0.04310         (----*-----)
Mag        -0.1358   0.0909   0.31756                  (----*-----)
Marys      -0.2464  -0.0197   0.20701               (-----*----)
                                       ---------+---------+---------+-------
                                            -0.40      0.00      0.40


station_1 = Chigger  subtracted from:
```

```
station_1    Lower   Center    Upper  ---------+---------+---------+-------
Coward's   -0.4084  -0.1817   0.0450           (----*-----)
HPBF       -0.7063  -0.4796  -0.2529   (-----*-----)
HPSC       -0.7610  -0.5343  -0.3076  (-----*----)
Mag        -0.4003  -0.1736   0.0531           (-----*----)
Marys      -0.5109  -0.2842  -0.0575        (-----*-----)
                                      ---------+---------+---------+-------
                                           -0.40      0.00      0.40


station_1 = Coward's  subtracted from:

station_1    Lower   Center    Upper  ---------+---------+---------+-------
HPBF       -0.5246  -0.2979  -0.0712        (-----*----)
HPSC       -0.5793  -0.3526  -0.1259       (----*-----)
Mag        -0.2186   0.0080   0.2347               (----*-----)
Marys      -0.3292  -0.1025   0.1242            (----*-----)
                                      ---------+---------+---------+-------
                                           -0.40      0.00      0.40


station_1 = HPBF  subtracted from:

station_1    Lower    Center   Upper  ---------+---------+---------+-------
HPSC       -0.2814  -0.05471  0.1720             (-----*----)
Mag         0.0793   0.30595  0.5326                      (-----*----)
Marys      -0.0313   0.19540  0.4221                   (-----*-----)
                                      ---------+---------+---------+-------
                                           -0.40      0.00      0.40


station_1 = HPSC  subtracted from:

station_1    Lower  Center   Upper  ---------+---------+---------+-------
Mag        0.13397  0.3607  0.5874                        (-----*-----)
Marys      0.02342  0.2501  0.4768                      (----*-----)
                                    ---------+---------+---------+-------
                                         -0.40      0.00      0.40


station_1 = Mag  subtracted from:

station_1    Lower   Center   Upper  ---------+---------+---------+-------
Marys      -0.3372  -0.1106  0.1161            (----*-----)
                                     ---------+---------+---------+-------
                                          -0.40      0.00      0.40
```

General Linear Model: Evenness versus station_1, Month

```
Factor     Type   Levels  Values
station_1  fixed       8  ABFair, ABHB, Chigger, Coward's, HPBF, HPSC, Mag,
                          Marys
Month      fixed       4  1, 2, 3, 4


Analysis of Variance for Evenness, using Adjusted SS for Tests

Source            DF    Seq SS   Adj SS   Adj MS      F      P
station_1          7   4.16762  4.16762  0.59537  17.97  0.000
Month              3   1.22624  1.22624  0.40875  12.34  0.000
station_1*Month   21   5.36760  5.36760  0.25560   7.71  0.000
Error            288   9.54248  9.54248  0.03313
```

```
Total            319  20.30394


S = 0.182026   R-Sq = 53.00%   R-Sq(adj) = 47.94%


Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Evenness
All Pairwise Comparisons among Levels of station_1
station_1 = ABFair  subtracted from:

station_1    Lower   Center     Upper  -------+---------+---------+---------
ABHB        0.0286   0.1521   0.27556                    (----*----)
Chigger    -0.0093   0.1141   0.23762                   (----*----)
Coward's   -0.1258  -0.0023   0.12117              (----*----)
HPBF       -0.2523  -0.1289  -0.00540         (----*----)
HPSC        0.0335   0.1570   0.28042                    (----*----)
Mag        -0.0280   0.0955   0.21899                  (----*----)
Marys      -0.2795  -0.1561  -0.03259        (----*----)
                                       -------+---------+---------+---------
                                           -0.25      0.00      0.25


station_1 = ABHB  subtracted from:

station_1    Lower   Center    Upper  -------+---------+---------+---------
Chigger    -0.1614  -0.0379   0.0855             (---*----)
Coward's   -0.2779  -0.1544  -0.0309        (----*----)
HPBF       -0.4044  -0.2810  -0.1575   (----*----)
HPSC       -0.1186   0.0049   0.1283              (----*----)
Mag        -0.1800  -0.0566   0.0669            (----*----)
Marys      -0.4316  -0.3082  -0.1847  (----*----)
                                      -------+---------+---------+---------
                                          -0.25      0.00      0.25


station_1 = Chigger  subtracted from:

station_1    Lower   Center    Upper  -------+---------+---------+---------
Coward's   -0.2399  -0.1165   0.0070         (----*----)
HPBF       -0.3665  -0.2430  -0.1196    (----*----)
HPSC       -0.0807   0.0428   0.1663                (----*----)
Mag        -0.1421  -0.0186   0.1048             (----*----)
Marys      -0.3937  -0.2702  -0.1467   (----*----)
                                      -------+---------+---------+---------
                                          -0.25      0.00      0.25


station_1 = Coward's  subtracted from:

station_1    Lower   Center     Upper  -------+---------+---------+---------
HPBF       -0.2500  -0.1266  -0.00310         (----*----)
HPSC        0.0358   0.1593   0.28273                    (----*----)
Mag        -0.0256   0.0978   0.22129                  (----*----)
Marys      -0.2772  -0.1538  -0.03029        (----*----)
                                       -------+---------+---------+---------
                                           -0.25      0.00      0.25


station_1 = HPBF  subtracted from:

station_1    Lower    Center    Upper  -------+---------+---------+---------
HPSC        0.1624   0.28582  0.40929                         (----*----)
```

```
Mag          0.1009   0.22439  0.34786                       (----*----)
Marys       -0.1507  -0.02719  0.09628             (----*----)
                                       -------+---------+---------+---------
                                           -0.25      0.00      0.25


station_1 = HPSC  subtracted from:

station_1    Lower   Center    Upper  -------+---------+---------+---------
Mag        -0.1849  -0.0614   0.0620           (----*---)
Marys      -0.4365  -0.3130  -0.1895  (---*----)
                                      -------+---------+---------+---------
                                          -0.25      0.00      0.25


station_1 = Mag  subtracted from:

station_1    Lower   Center    Upper  -------+---------+---------+---------
Marys      -0.3750  -0.2516  -0.1281    (----*----)
                                      -------+---------+---------+---------
                                          -0.25      0.00      0.25
```

General Linear Model: Richness versus station_1, Month

```
Factor     Type   Levels  Values
station_1  fixed       8  ABFair, ABHB, Chigger, Coward's, HPBF, HPSC, Mag,
                          Marys
Month      fixed       4  1, 2, 3, 4


Analysis of Variance for Richness, using Adjusted SS for Tests

Source            DF    Seq SS    Adj SS   Adj MS      F      P
station_1          7  1103.200  1103.200  157.600  67.66  0.000
Month              3   154.825   154.825   51.608  22.16  0.000
station_1*Month   21   400.725   400.725   19.082   8.19  0.000
Error            288   670.800   670.800    2.329
Total            319  2329.550


S = 1.52616   R-Sq = 71.20%   R-Sq(adj) = 68.11%

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Richness
All Pairwise Comparisons among Levels of station_1
station_1 = ABFair  subtracted from:

station_1   Lower   Center   Upper  ----+---------+---------+---------+--
ABHB       -1.385  -0.3500  0.6852           (--*--)
Chigger     0.965   2.0000  3.0352                  (--*--)
Coward's    2.015   3.0500  4.0852                     (--*--)
HPBF       -0.360   0.6750  1.7102              (--*--)
HPSC       -1.885  -0.8500  0.1852          (--*--)
Mag         0.215   1.2500  2.2852                (--*--)
Marys       4.090   5.1250  6.1602                           (--*--)
                                    ----+---------+---------+---------+--
                                     -3.5       0.0       3.5       7.0


station_1 = ABHB  subtracted from:

station_1   Lower   Center   Upper  ----+---------+---------+---------+--
Chigger     1.315   2.3500  3.3852                   (--*--)
```

```
Coward's    2.365   3.4000  4.4352                        (--*--)
HPBF       -0.010   1.0250  2.0602                 (--*--)
HPSC       -1.535  -0.5000  0.5352             (--*--)
Mag         0.565   1.6000  2.6352                   (--*--)
Marys       4.440   5.4750  6.5102                              (--*--)
                                    ----+---------+---------+---------+--
                                     -3.5       0.0       3.5       7.0


station_1 = Chigger  subtracted from:

station_1   Lower  Center   Upper  ----+---------+---------+---------+--
Coward's    0.015   1.050   2.085                (--*--)
HPBF       -2.360  -1.325  -0.290         (--*--)
HPSC       -3.885  -2.850  -1.815     (--*--)
Mag        -1.785  -0.750   0.285           (--*--)
Marys       2.090   3.125   4.160                      (--*--)
                                   ----+---------+---------+---------+--
                                    -3.5       0.0       3.5       7.0


station_1 = Coward's  subtracted from:

station_1   Lower  Center   Upper  ----+---------+---------+---------+--
HPBF       -3.410  -2.375  -1.340      (--*--)
HPSC       -4.935  -3.900  -2.865  (--*--)
Mag        -2.835  -1.800  -0.765        (--*--)
Marys       1.040   2.075   3.110                   (--*--)
                                   ----+---------+---------+---------+--
                                    -3.5       0.0       3.5       7.0


station_1 = HPBF  subtracted from:

station_1   Lower  Center    Upper  ----+---------+---------+---------+--
HPSC       -2.560  -1.525  -0.4898         (--*--)
Mag        -0.460   0.575   1.6102               (--*--)
Marys       3.415   4.450   5.4852                          (--*--)
                                    ----+---------+---------+---------+--
                                     -3.5       0.0       3.5       7.0


station_1 = HPSC  subtracted from:

station_1  Lower  Center  Upper  ----+---------+---------+---------+--
Mag        1.065   2.100  3.135                  (--*--)
Marys      4.940   5.975  7.010                             (--*--)
                                 ----+---------+---------+---------+--
                                  -3.5       0.0       3.5       7.0


station_1 = Mag  subtracted from:

station_1  Lower  Center  Upper  ----+---------+---------+---------+--
Marys      2.840   3.875  4.910                       (--*--)
                                 ----+---------+---------+---------+--
                                  -3.5       0.0       3.5       7.0
```

General Linear Model: Total Numbers versus station_1, Month

```
Factor     Type   Levels  Values
```

```
station_1  fixed       8  ABFair, ABHB, Chigger, Coward's, HPBF, HPSC, Mag,
                          Marys
Month      fixed       4  1, 2, 3, 4


Analysis of Variance for Total Numbers, using Adjusted SS for Tests

Source            DF    Seq SS    Adj SS   Adj MS      F      P
station_1          7  11608274  11608274  1658325  68.39  0.000
Month              3    382191    382191   127397   5.25  0.002
station_1*Month   21   2863314   2863314   136348   5.62  0.000
Error            288   6983462   6983462    24248
Total            319  21837241


S = 155.718   R-Sq = 68.02%   R-Sq(adj) = 64.58%

Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Total Numbers
All Pairwise Comparisons among Levels of station_1
station_1 = ABFair  subtracted from:

station_1   Lower  Center   Upper  --------+---------+---------+--------
ABHB       -133.8  -28.15   77.47      (--*---)
Chigger     -83.5   22.15  127.77       (---*--)
Coward's     44.6  150.25  255.87           (---*---)
HPBF        -56.5   49.10  154.72        (---*--)
HPSC        -81.9   23.73  129.35       (---*--)
Mag        -102.0    3.63  109.25       (--*---)
Marys       481.7  587.35  692.97                         (---*--)
                                   --------+---------+---------+--------
                                           0       300       600


station_1 = ABHB  subtracted from:

station_1   Lower  Center  Upper  --------+---------+---------+--------
Chigger    -55.32   50.30  155.9       (---*--)
Coward's    72.78  178.40  284.0           (---*--)
HPBF       -28.37   77.25  182.9        (---*--)
HPSC       -53.75   51.87  157.5       (---*--)
Mag        -73.85   31.77  137.4       (--*---)
Marys      509.88  615.50  721.1                         (---*--)
                                  --------+---------+---------+--------
                                          0       300       600


station_1 = Chigger  subtracted from:

station_1   Lower  Center   Upper  --------+---------+---------+--------
Coward's     22.5  128.10  233.72           (--*---)
HPBF        -78.7   26.95  132.57       (---*--)
HPSC       -104.0    1.57  107.20       (--*---)
Mag        -124.1  -18.53   87.10      (--*---)
Marys       459.6  565.20  670.82                        (---*--)
                                   --------+---------+---------+--------
                                           0       300       600


station_1 = Coward's  subtracted from:

station_1   Lower  Center   Upper  --------+---------+---------+--------
HPBF       -206.8  -101.1    4.47   (---*--)
```

```
HPSC       -232.1  -126.5  -20.90  (---*--)
Mag        -252.2  -146.6  -41.00  (--*---)
Marys       331.5   437.1  542.72                     (---*--)
                                   --------+---------+---------+--------
                                           0       300       600


station_1 = HPBF  subtracted from:

station_1   Lower  Center   Upper  --------+---------+---------+--------
HPSC       -131.0  -25.38   80.25      (--*---)
Mag        -151.1  -45.48   60.15     (--*---)
Marys       432.6  538.25  643.87                        (---*--)
                                   --------+---------+---------+--------
                                           0       300       600


station_1 = HPSC  subtracted from:

station_1   Lower  Center   Upper  --------+---------+---------+--------
Mag        -125.7  -20.10   85.52      (--*---)
Marys       458.0  563.63  669.25                         (---*--)
                                   --------+---------+---------+--------
                                           0       300       600


station_1 = Mag  subtracted from:

station_1  Lower  Center  Upper  --------+---------+---------+--------
Marys      478.1   583.7  689.3                          (--*---)
                                 --------+---------+---------+--------
                                         0       300       600
```

General Linear Model: DO versus site, month

Factor	Type	Levels	Values
site	fixed	8	ABFAIR, ABHB, CHIGG, COW, HPBF, HPSC, MAG, MARY
month	fixed	4	1, 2, 3, 4

Analysis of Variance for DO, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
site	7	331.590	331.590	47.370	84.03	0.000
month	3	1.547	1.547	0.516	0.91	0.439
site*month	21	265.229	265.229	12.630	22.40	0.000
Error	64	36.079	36.079	0.564		
Total	95	634.444				

S = 0.750818   R-Sq = 94.31%   R-Sq(adj) = 91.56%

Unusual Observations for DO

Obs	DO	Fit	SE Fit	Residual	St Resid	
32	14.0000	11.6000	0.4335	2.4000	3.91	R
44	6.5000	5.2333	0.4335	1.2667	2.07	R
63	14.0000	11.6000	0.4335	2.4000	3.91	R
64	10.0000	11.6000	0.4335	-1.6000	-2.61	R
95	8.8000	11.6000	0.4335	-2.8000	-4.57	R

```
R denotes an observation with a large standardized residual.


Tukey 95.0% Simultaneous Confidence Intervals
Response Variable DO
All Pairwise Comparisons among Levels of site
site = ABFAIR  subtracted from:

site    Lower  Center   Upper  ---+---------+---------+---------+---
ABHB   -2.827  -1.867  -0.906      (--*--)
CHIGG  -3.919  -2.958  -1.998  (--*--)
COW    -3.002  -2.042  -1.081     (--*--)
HPBF   -3.899  -2.939  -1.979  (--*--)
HPSC   -1.777  -0.817   0.144         (--*--)
MAG    -2.494  -1.533  -0.573       (--*--)
MARY    2.165   3.125   4.085                      (--*---)
                               ---+---------+---------+---------+---
                               -3.0       0.0       3.0       6.0


site = ABHB  subtracted from:

site    Lower  Center    Upper  ---+---------+---------+---------+---
CHIGG  -2.052  -1.092  -0.1315        (--*---)
COW    -1.135  -0.175   0.7852           (--*---)
HPBF   -2.033  -1.072  -0.1123        (--*---)
HPSC    0.090   1.050   2.0102               (---*--)
MAG    -0.627   0.333   1.2935             (--*--)
MARY    4.031   4.992   5.9518                           (---*--)
                                ---+---------+---------+---------+---
                                -3.0       0.0       3.0       6.0


site = CHIGG  subtracted from:

site    Lower   Center   Upper  ---+---------+---------+---------+---
COW   -0.0435  0.91667  1.8768              (--*--)
HPBF  -0.9410  0.01917  0.9793           (--*--)
HPSC   1.1815  2.14167  3.1018                  (--*--)
MAG    0.4648  1.42500  2.3852                (--*--)
MARY   5.1232  6.08333  7.0435                               (--*--)
                                ---+---------+---------+---------+---
                                -3.0       0.0       3.0       6.0


site = COW  subtracted from:

site   Lower   Center    Upper  ---+---------+---------+---------+---
HPBF  -1.858  -0.8975  0.06267         (--*--)
HPSC   0.265   1.2250  2.18517                (--*--)
MAG   -0.452   0.5083  1.46850             (---*--)
MARY   4.206   5.1667  6.12684                            (--*--)
                                ---+---------+---------+---------+---
                                -3.0       0.0       3.0       6.0


site = HPBF  subtracted from:

site   Lower  Center  Upper  ---+---------+---------+---------+---
HPSC  1.1623   2.122  3.083                 (--*--)
MAG   0.4457   1.406  2.366              (---*--)
MARY  5.1040   6.064  7.024                             (--*--)
```

```
                              ---+---------+---------+---------+---
                              -3.0       0.0       3.0       6.0


site = HPSC  subtracted from:

site   Lower   Center   Upper  ---+---------+---------+---------+---
MAG   -1.677  -0.7167  0.2435         (---*--)
MARY   2.981   3.9417  4.9018                         (--*--)
                               ---+---------+---------+---------+---
                               -3.0       0.0       3.0       6.0


site = MAG  subtracted from:

site  Lower  Center  Upper  ---+---------+---------+---------+---
MARY  3.698   4.658  5.619                        (---*--)
                            ---+---------+---------+---------+---
                            -3.0       0.0       3.0       6.0
```

General Linear Model: Width versus site, month

```
Factor  Type   Levels  Values
site    fixed       8  ABFAIR, ABHB, CHIGG, COW, HPBF, HPSC, MAG, MARY
month   fixed       4  1, 2, 3, 4


Analysis of Variance for Width, using Adjusted SS for Tests

Source      DF   Seq SS   Adj SS  Adj MS      F      P
site         7  4105.72  4105.72  586.53  64.36  0.000
month        3    62.57    62.57   20.86   2.29  0.087
site*month  21   441.04   441.04   21.00   2.30  0.006
Error       64   583.23   583.23    9.11
Total       95  5192.57


S = 3.01876   R-Sq = 88.77%   R-Sq(adj) = 83.33%


Tukey 95.0% Simultaneous Confidence Intervals
Response Variable Width
All Pairwise Comparisons among Levels of site
site = ABFAIR  subtracted from:

site    Lower  Center   Upper   -+---------+---------+---------+-----
ABHB   -4.494  -0.633   3.227         (--*---)
CHIGG  -3.206   0.654   4.515          (---*---)
COW     0.715   4.576   8.436              (---*--)
HPBF   -3.817   0.043   3.904         (---*---)
HPSC    0.494   4.354   8.215             (---*---)
MAG    -5.965  -2.104   1.756       (---*---)
MARY   15.756  19.617  23.477                             (---*--)
                                -+---------+---------+---------+-----
                               -10         0        10        20


site = ABHB  subtracted from:

site    Lower  Center   Upper   -+---------+---------+---------+-----
CHIGG  -2.573   1.288   5.148          (---*---)
```

```
COW     1.349   5.209   9.070             (---*---)
HPBF   -3.184   0.677   4.537         (---*---)
HPSC    1.127   4.987   8.848             (---*---)
MAG    -5.331  -1.471   2.390       (---*--)
MARY   16.390  20.250  24.110                            (---*---)
                                  -+---------+---------+---------+-----
                                 -10         0        10        20


site = CHIGG  subtracted from:

site   Lower  Center   Upper   -+---------+---------+---------+-----
COW    0.061   3.922   7.782             (---*---)
HPBF  -4.471  -0.611   3.250         (--*---)
HPSC  -0.160   3.700   7.560             (---*---)
MAG   -6.619  -2.758   1.102      (---*---)
MARY  15.102  18.963  22.823                            (---*---)
                               -+---------+---------+---------+-----
                              -10         0        10        20


site = COW  subtracted from:

site   Lower  Center   Upper   -+---------+---------+---------+-----
HPBF   -8.39  -4.532  -0.672      (--*---)
HPSC   -4.08  -0.222   3.639          (---*---)
MAG   -10.54  -6.680  -2.820   (---*---)
MARY   11.18  15.041  18.901                        (---*---)
                               -+---------+---------+---------+-----
                              -10         0        10        20


site = HPBF  subtracted from:

site   Lower  Center   Upper   -+---------+---------+---------+-----
HPSC   0.450   4.311   8.171             (---*---)
MAG   -6.008  -2.147   1.713       (---*---)
MARY  15.713  19.573  23.434                             (---*--)
                               -+---------+---------+---------+-----
                              -10         0        10        20


site = HPSC  subtracted from:

site   Lower  Center   Upper   -+---------+---------+---------+-----
MAG   -10.32  -6.458  -2.598    (---*--)
MARY   11.40  15.263  19.123                        (---*---)
                               -+---------+---------+---------+-----
                              -10         0        10        20


site = MAG  subtracted from:

site  Lower  Center  Upper   -+---------+---------+---------+-----
MARY  17.86   21.72  25.58                             (---*---)
                             -+---------+---------+---------+-----
                            -10         0        10        20
```

General Linear Model: emerg versus site, month

```
Factor  Type   Levels  Values
site    fixed       8  ABFAIR, ABHB, CHIGG, COW, HPBF, HPSC, MAG, MARY
month   fixed       4  1, 2, 3, 4


Analysis of Variance for emerg, using Adjusted SS for Tests

Source      DF   Seq SS   Adj SS  Adj MS     F      P
site         7   3743.6   3743.6   534.8  2.57  0.021
month        3    401.7    401.7   133.9  0.64  0.590
site*month  21   6114.4   6114.4   291.2  1.40  0.153
Error       64  13311.3  13311.3   208.0
Total       95  23571.0


S = 14.4218   R-Sq = 43.53%   R-Sq(adj) = 16.17%


Tukey 95.0% Simultaneous Confidence Intervals
Response Variable emerg
All Pairwise Comparisons among Levels of site
site = ABFAIR  subtracted from:

site    Lower   Center  Upper  -------+---------+---------+---------
ABHB    -1.86  16.5833  35.03                (---------*---------)
CHIGG   -7.36  11.0833  29.53             (---------*--------)
COW    -11.69   6.7500  25.19           (--------*---------)
HPBF    -8.11  10.3333  28.78             (--------*--------)
HPSC   -17.86   0.5833  19.03        (--------*---------)
MAG    -17.94   0.5000  18.94        (--------*--------)
MARY    -3.53  14.9167  33.36               (--------*---------)
                               -------+---------+---------+---------
                                    -20         0        20


site = ABHB  subtracted from:

site    Lower  Center   Upper  -------+---------+---------+---------
CHIGG  -23.94   -5.50  12.943      (--------*--------)
COW    -28.28   -9.83   8.610    (--------*--------)
HPBF   -24.69   -6.25  12.193      (--------*--------)
HPSC   -34.44  -16.00   2.443  (--------*--------)
MAG    -34.53  -16.08   2.360  (--------*--------)
MARY   -20.11   -1.67  16.776        (--------*--------)
                               -------+---------+---------+---------
                                    -20         0        20


site = CHIGG  subtracted from:

site   Lower  Center   Upper  -------+---------+---------+---------
COW   -22.78   -4.33  14.110       (--------*--------)
HPBF  -19.19   -0.75  17.693        (---------*--------)
HPSC  -28.94  -10.50   7.943    (--------*--------)
MAG   -29.03  -10.58   7.860   (---------*--------)
MARY  -14.61    3.83  22.276          (--------*--------)
                              -------+---------+---------+---------
                                   -20         0        20


site = COW  subtracted from:

site   Lower  Center  Upper  -------+---------+---------+---------
```

```
HPBF  -14.86   3.583  22.03            (--------*--------)
HPSC  -24.61  -6.167  12.28       (--------*--------)
MAG   -24.69  -6.250  12.19       (--------*--------)
MARY  -10.28   8.167  26.61              (--------*--------)
                             -------+---------+---------+---------
                                  -20         0        20


site = HPBF  subtracted from:

site   Lower  Center   Upper  -------+---------+---------+---------
HPSC  -28.19  -9.750   8.693     (--------*--------)
MAG   -28.28  -9.833   8.610     (--------*--------)
MARY  -13.86   4.583  23.026            (--------*---------)
                              -------+---------+---------+---------
                                   -20         0        20


site = HPSC  subtracted from:

site   Lower   Center  Upper  -------+---------+---------+---------
MAG   -18.53  -0.0833  18.36         (--------*--------)
MARY   -4.11  14.3333  32.78                (--------*--------)
                              -------+---------+---------+---------
                                   -20         0        20


site = MAG  subtracted from:

site   Lower  Center  Upper  -------+---------+---------+---------
MARY  -4.026   14.42  32.86                (--------*--------)
                             -------+---------+---------+---------
                                  -20         0        20
```

General Linear Model: depth versus site, month

```
Factor  Type   Levels  Values
site    fixed       8  ABFAIR, ABHB, CHIGG, COW, HPBF, HPSC, MAG, MARY
month   fixed       4  1, 2, 3, 4


Analysis of Variance for depth, using Adjusted SS for Tests

Source      DF   Seq SS   Adj SS  Adj MS      F      P
site         7  22.1823  22.1823  3.1689  15.32  0.000
month        3   2.9374   2.9374  0.9791   4.73  0.005
site*month  21  21.8583  21.8583  1.0409   5.03  0.000
Error       64  13.2383  13.2383  0.2068
Total       95  60.2162


S = 0.454807   R-Sq = 78.02%   R-Sq(adj) = 67.37%


Tukey 95.0% Simultaneous Confidence Intervals
Response Variable depth
All Pairwise Comparisons among Levels of site
site = ABFAIR  subtracted from:

site     Lower  Center   Upper  ------+---------+---------+---------+
ABHB    0.0975  0.6792  1.2608                  (----*----)
CHIGG   0.5017  1.0833  1.6650                     (----*----)
```

```
COW      0.9225  1.5042  2.0858                          (----*---)
HPBF    -0.3608  0.2208  0.8025               (----*----)
HPSC     0.6225  1.2042  1.7858                       (----*----)
MAG     -0.1358  0.4458  1.0275                 (----*----)
MARY     0.3184  0.9000  1.4816                     (---*----)
                                   ------+---------+---------+---------+
                                      -1.2       0.0       1.2       2.4


site = ABHB  subtracted from:

site    Lower   Center   Upper   ------+---------+---------+---------+
CHIGG  -0.177   0.4042  0.9858                 (---*----)
COW     0.243   0.8250  1.4066                    (----*----)
HPBF   -1.040  -0.4583  0.1233         (----*----)
HPSC   -0.057   0.5250  1.1066                  (---*----)
MAG    -0.815  -0.2333  0.3483           (----*----)
MARY   -0.361   0.2208  0.8025               (----*----)
                                   ------+---------+---------+---------+
                                      -1.2       0.0       1.2       2.4


site = CHIGG  subtracted from:

site   Lower   Center    Upper   ------+---------+---------+---------+
COW   -0.161   0.4208   1.0025                 (----*---)
HPBF  -1.444  -0.8625  -0.2809      (----*----)
HPSC  -0.461   0.1208   0.7025              (----*----)
MAG   -1.219  -0.6375  -0.0559        (----*----)
MARY  -0.765  -0.1833   0.3983            (---*----)
                                   ------+---------+---------+---------+
                                      -1.2       0.0       1.2       2.4


site = COW  subtracted from:

site   Lower  Center    Upper  ------+---------+---------+---------+
HPBF  -1.865  -1.283  -0.7017  (----*----)
HPSC  -0.882  -0.300   0.2816           (----*---)
MAG   -1.640  -1.058  -0.4767    (----*----)
MARY  -1.186  -0.604  -0.0225        (----*----)
                               ------+---------+---------+---------+
                                  -1.2       0.0       1.2       2.4


site = HPBF  subtracted from:

site    Lower  Center   Upper  ------+---------+---------+---------+
HPSC   0.4017  0.9833  1.5650                     (----*----)
MAG   -0.3566  0.2250  0.8066             (----*----)
MARY   0.0975  0.6792  1.2608                 (----*----)
                               ------+---------+---------+---------+
                                  -1.2       0.0       1.2       2.4


site = HPSC  subtracted from:

site   Lower   Center    Upper   ------+---------+---------+---------+
MAG   -1.340  -0.7583  -0.1767       (----*----)
MARY  -0.886  -0.3042   0.2775           (---*----)
                                   ------+---------+---------+---------+
                                      -1.2       0.0       1.2       2.4
```

```
site = MAG  subtracted from:

site    Lower  Center  Upper  ------+---------+---------+---------+
MARY  -0.1275  0.4542  1.036                (----*----)
                              ------+---------+---------+---------+
                                 -1.2       0.0       1.2       2.4
```

APPENDIX VIII

Statistics Reports: Correlations

Electroshocking Data Correlations:

Correlations: ES CENTRAR, Cichlids

```
Pearson correlation of CENTRAR and Cichlids = -0.110
P-Value = 0.417
```

Correlations: Invasive mean, Native mean (ES)

```
Pearson correlation of Invasive mean and Native mean = 0.193
P-Value = 0.281
```

Correlations: Cichlids, CENTRAR

```
Pearson correlation of Cichlids and CENTRAR = -0.110
P-Value = 0.417
```

Correlations: Cichlids, H

```
Pearson correlation of Cichlids and H = 0.043
P-Value = 0.751
```

Correlations: Cichlids, E

```
Pearson correlation of Cichlids and E = 0.048
P-Value = 0.724
```

Correlations: Cichlids, Richness

```
Pearson correlation of Cichlids and Richness = -0.017
P-Value = 0.902
```

Seine Data Correlations:

Correlations: Richness, Cichlids

```
Pearson correlation of Richness and Cichlids = 0.141
P-Value = 0.441
```

Correlations: CENTRAR, Cichlids

```
Pearson correlation of CENTRAR and Cichlids = 0.118
P-Value = 0.521
```

Correlations: Cichlids, CENTRAR

```
Pearson correlation of Cichlids and CENTRAR = 0.118
P-Value = 0.521
```

Correlations: Shannon-Wiener, Cichlids

Pearson correlation of Shannon-Wiener and Cichlids = 0.003
P-Value = 0.986

Correlations: Evenness, Cichlids

Pearson correlation of Evenness and Cichlids = -0.077
P-Value = 0.676

APPENDIX VIV:

Statistics Reports: Cluster Analysis

Seine data (Minitab 15.0)
Cluster Analysis of Observations: Anchoa mitch, Cyprinella l, Pimephales v, ...

Squared Euclidean Distance, Ward Linkage
Amalgamation Steps

Step	Number of clusters	Similarity level	Distance level	Clusters joined		New cluster	Number of obs. in new cluster
1	31	99.999	364	19	20	19	2
2	30	99.999	396	6	28	6	2
3	29	99.999	644	10	27	10	2
4	28	99.998	833	4	10	4	3
5	27	99.998	1009	12	26	12	2
6	26	99.997	1319	19	30	19	3
7	25	99.996	1739	11	19	11	4
8	24	99.996	1822	4	7	4	4
9	23	99.996	1880	3	6	3	3
10	22	99.995	2444	22	24	22	2
11	21	99.984	7583	4	18	4	5
12	20	99.984	7845	12	22	12	4
13	19	99.984	7956	3	11	3	7
14	18	99.978	10578	4	9	4	6
15	17	99.960	19470	8	23	8	2
16	16	99.954	22318	1	25	1	2
17	15	99.947	25579	2	4	2	7
18	14	99.832	81346	2	3	2	14
19	13	99.818	87993	5	8	5	3
20	12	99.816	88856	12	29	12	5
21	11	99.792	100667	1	21	1	3
22	10	99.173	399622	31	32	31	2
23	9	98.916	523821	1	5	1	6
24	8	98.344	800619	14	15	14	2
25	7	98.068	933946	2	12	2	19
26	6	95.016	2409375	13	31	13	3
27	5	85.224	7143008	1	17	1	7
28	4	84.766	7364731	1	2	1	26
29	3	83.815	7824336	14	16	14	3
30	2	51.852	23275880	13	14	13	6
31	1	-168.030	129572895	1	13	1	32

Final Partition
Number of clusters: 3

	Number of observations	Within cluster sum of squares	Average distance from centroid	Maximum distance from centroid
Cluster1	26	8219073	428.24	1875.71
Cluster2	3	1404499	664.02	896.17
Cluster3	3	4312477	1149.96	1614.96

Cluster Centroids

Variable	Cluster1	Cluster2	Cluster3	Grand centroid
Anchoa mitchilli	74.731	0.00	0.00	60.72
Cyprinella lutrensis	1.192	5.67	16.33	3.03
Pimephales vigilax	4.038	68.00	77.33	16.91
Noturus gyrinus	0.077	17.67	13.67	3.00
Cyprinodon variegatus	5.846	13.00	4.33	6.38
Fundulus chrysotus	3.577	2.00	6.33	3.69
Fundulus olivaceus/ notatus	8.808	5.33	0.33	7.69
Gambusia affinis	405.808	2609.33	5121.33	1054.47
Poecilia latipinna	32.538	254.67	106.00	60.25
Menida beryllina	11.769	549.67	1743.33	224.53
Lepomis macrochirus	4.192	10.67	16.33	5.94
Lepomis microlophus	2.500	16.67	16.00	5.09
Lepomis sp. (juvenile)	1.923	1.33	0.67	1.75
Micropterus punctulatus	0.846	0.67	0.67	0.81
Micropterus salmoides	1.000	0.33	0.67	0.91
Cichlasomo cyanoguttatum	31.308	75.00	44.00	36.59
Oreochromis sp. (Tilapia)	11.038	3.33	17.67	10.94
Notemigonus crysoleucas	3.423	1.33	3.67	3.25

Distances Between Cluster Centroids

	Cluster1	Cluster2	Cluster3
Cluster1	0.00	2281.77	5025.13
Cluster2	2281.77	0.00	2785.43
Cluster3	5025.13	2785.43	0.00

Cluster ES data (Minitab 15 English)

APPENDIX X:

Statistics Reports: Discriminant Stepwise Multiple Regression

Discriminat Analysis (SPSS 15.0 for Windows) Seine data

```
GET DATA /TYPE=XLS
   /FILE='C:\Documents and Settings\RamirezDi\Desktop\Clusterdiscriminatest'+
 'epanalysis.sav.xls'
   /SHEET=name 'Sheet1'
   /CELLRANGE=full
   /READNAMES=on
   /ASSUMEDSTRWIDTH=32767.
DATASET NAME DataSet1 WINDOW=FRONT.
DATASET ACTIVATE DataSet1.
DATASET CLOSE DataSet0.
DISCRIMINANT
  /GROUPS=Cluster(1 3)
  /VARIABLES=pH Cond ammonia water_temp phosphate nitrate avgsecci
  avgWentworth avgveg avgemerg avgdepth avgvelocity avgwidth AVGDO
  HabitatComplexity Cichlids
  /ANALYSIS ALL
   /METHOD=WILKS
   /FIN= 3.84
   /FOUT= 2.71
  /PRIORS  EQUAL
   /HISTORY
  /STATISTICS=COEFF TABLE CROSSVALID
  /CLASSIFY=NONMISSING POOLED .
```

Discriminant

[DataSet1]

Analysis Case Processing Summary

Unweighted Cases		N	Percent
Valid		32	100.0
Excluded	Missing or out-of-range group codes	0	.0
	At least one missing discriminating variable	0	.0
	Both missing or out-of-range group codes and at least one missing discriminating variable	0	.0
	Total	0	.0
Total		32	100.0

Group Statistics

Cluster		Valid N (listwise) Unweighted	Weighted
1	pH	26	26.000
	Cond	26	26.000
	ammonia	26	26.000
	water_temp	26	26.000
	phosphate	26	26.000
	nitrate	26	26.000
	avg secci	26	26.000
	avg Wentworth	26	26.000
	avg veg	26	26.000
	avg emerg	26	26.000
	avg depth	26	26.000
	avg velocity	26	26.000
	avg width	26	26.000
	AVG DO	26	26.000
	Habitat Complexity	26	26.000
	Cichlids	26	26.000
2	pH	3	3.000
	Cond	3	3.000
	ammonia	3	3.000
	water_temp	3	3.000
	phosphate	3	3.000
	nitrate	3	3.000
	avg secci	3	3.000
	avg Wentworth	3	3.000
	avg veg	3	3.000
	avg emerg	3	3.000
	avg depth	3	3.000
	avg velocity	3	3.000
	avg width	3	3.000
	AVG DO	3	3.000
	Habitat Complexity	3	3.000
	Cichlids	3	3.000
3	pH	3	3.000
	Cond	3	3.000
	ammonia	3	3.000
	water_temp	3	3.000
	phosphate	3	3.000
	nitrate	3	3.000
	avg secci	3	3.000
	avg Wentworth	3	3.000
	avg veg	3	3.000
	avg emerg	3	3.000
	avg depth	3	3.000
	avg velocity	3	3.000
	avg width	3	3.000
	AVG DO	3	3.000
	Habitat Complexity	3	3.000
	Cichlids	3	3.000
Total	pH	32	32.000

Analysis 1
Stepwise Statistics

Variables Entered/Removed[a,b,c,d]

Step	Entered	Wilks' Lambda							
						Exact F			
		Statistic	df1	df2	df3	Statistic	df1	df2	Sig.
1	avg width	.318	1	2	29.000	31.083	2	29.000	.000
2	pH	.232	2	2	29.000	15.050	4	56.000	.000

At each step, the variable that minimizes the overall Wilks' Lambda is entered.

a. Maximum number of steps is 32.

b. Minimum partial F to enter is 3.84.

c. Maximum partial F to remove is 2.71.

d. F level, tolerance, or VIN insufficient for further computation.

Variables in the Analysis

Step		Tolerance	F to Remove	Wilks' Lambda
1	avg width	1.000	31.083	
2	avg width	1.000	14.407	.471
	pH	1.000	5.175	.318

Variables Not in the Analysis

Step		Tolerance	Min. Tolerance	F to Enter	Wilks' Lambda
0	pH	1.000	1.000	16.268	.471
	Cond	1.000	1.000	.538	.964
	ammonia	1.000	1.000	.284	.981
	water_temp	1.000	1.000	1.017	.934
	phosphate	1.000	1.000	3.072	.825
	nitrate	1.000	1.000	.075	.995
	avg secci	1.000	1.000	6.743	.683
	avg Wentworth	1.000	1.000	3.954	.786
	avg veg	1.000	1.000	.265	.982
	avg emerg	1.000	1.000	.887	.942
	avg depth	1.000	1.000	.374	.975
	avg velocity	1.000	1.000	1.175	.925
	avg width	1.000	1.000	31.083	.318
	AVG DO	1.000	1.000	10.483	.580
	Habitat Complexity	1.000	1.000	13.235	.523
	Cichlids	1.000	1.000	.403	.973
1	pH	1.000	1.000	5.175	.232
	Cond	.987	.987	.683	.303
	ammonia	.934	.934	.391	.309
	water_temp	.960	.960	.242	.313
	phosphate	.939	.939	.578	.306
	nitrate	.955	.955	.661	.304
	avg secci	.952	.952	1.126	.294
	avg Wentworth	.940	.940	.626	.304
	avg veg	.999	.999	.141	.315
	avg emerg	.999	.999	.381	.310
	avg depth	.728	.728	2.502	.270
	avg velocity	.970	.970	1.106	.295
	AVG DO	.993	.993	3.610	.253
	Habitat Complexity	.917	.917	2.943	.263
	Cichlids	.954	.954	1.080	.295
2	Cond	.987	.987	.652	.222
	ammonia	.916	.916	.205	.229
	water_temp	.854	.854	.674	.221
	phosphate	.939	.939	.517	.224
	nitrate	.951	.951	.390	.226
	avg secci	.868	.868	1.936	.203
	avg Wentworth	.768	.768	1.593	.208
	avg veg	.996	.996	.183	.229
	avg emerg	.999	.999	.266	.228
	avg depth	.389	.389	.051	.231
	avg velocity	.755	.755	2.461	.196
	AVG DO	.692	.692	1.063	.215
	Habitat Complexity	.887	.887	3.300	.187
	Cichlids	.935	.935	1.330	.211

Wilks' Lambda

Step	Number of Variables	Lambda	df 1	df 2	df 3	Exact F			
						Statistic	df 1	df 2	Sig.
1	1	.318	1	2	29	31.083	2	29.000	.000
2	2	.232	2	2	29	15.050	4	56.000	.000

Summary of Canonical Discriminant Functions

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	3.198[a]	99.2	99.2	.873
2	.026[a]	.8	100.0	.158

a. First 2 canonical discriminant functions were used in the analysis.

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1 through 2	.232	41.608	4	.000
2	.975	.724	1	.395

Standardized Canonical Discriminant Function Coefficients

	Function	
	1	2
pH	.577	.817
avg width	.809	-.588

Structure Matrix

	Function	
	1	2
avg width	.817*	-.576
water_temp[a]	.351*	.151
Cichlids[a]	-.254*	.012
phosphate[a]	.206*	-.137
Cond[a]	-.092*	.066
avg veg[a]	.056*	.032
pH	.588	.809*
avg depth[a]	.090	-.777*
avg Wentworth[a]	.039	.480*
avg velocity[a]	-.127	-.478*
AVG DO[a]	.383	.402*
avg secch[a]	-.012	.364*
Habitat Complexity[a]	-.135	.308*
ammonia[a]	-.134	.257*
nitrate[a]	.140	-.170*
avg emerg[a]	-.020	.025*

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions
Variables ordered by absolute size of correlation within function.

*. Largest absolute correlation between each variable and any discriminant function

a. This variable not used in the analysis.

Functions at Group Centroids

	Function	
Cluster	1	2
1	-.740	.031
2	1.532	-.454
3	4.880	.184

Unstandardized canonical discriminant functions evaluated at group means

Classification Statistics

Classification Processing Summary

Processed		32
Excluded	Missing or out-of-range group codes	0
	At least one missing discriminating variable	0
Used in Output		32

Prior Probabilities for Groups

Cluster	Prior	Cases Used in Analysis Unweighted	Cases Used in Analysis Weighted
1	.333	26	26.000
2	.333	3	3.000
3	.333	3	3.000
Total	1.000	32	32.000

Classification Function Coefficients

	Cluster 1	Cluster 2	Cluster 3
pH	45.920	48.189	54.280
avg width	.637	1.155	1.723
(Constant)	-176.003	-201.718	-266.940

Fisher's linear discriminant functions

Classification Results[b,c]

		Cluster	Predicted Group Membership 1	Predicted Group Membership 2	Predicted Group Membership 3	Total
Original	Count	1	24	2	0	26
		2	2	0	1	3
		3	0	0	3	3
	%	1	92.3	7.7	.0	100.0
		2	66.7	.0	33.3	100.0
		3	.0	.0	100.0	100.0
Cross-validated[a]	Count	1	24	2	0	26
		2	2	0	1	3
		3	0	0	3	3
	%	1	92.3	7.7	.0	100.0
		2	66.7	.0	33.3	100.0
		3	.0	.0	100.0	100.0

a. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

b. 84.4% of original grouped cases correctly classified.

c. 84.4% of cross-validated grouped cases correctly classified.

Discriminat Analysis ES data (SPSS 15.0 for Windows)

```
GET DATA /TYPE=XLS
   /FILE='F:\research data\stats\spssstepwise\ESCPUEdiscriminate.xls'
   /SHEET=name 'Sheet1'
   /CELLRANGE=full
   /READNAMES=on
   /ASSUMEDSTRWIDTH=32767.
```

```
DATASET NAME DataSet1 WINDOW=FRONT.
DISCRIMINANT
  /GROUPS=Cluster(1 3)
  /VARIABLES=pH Cond NH4 water_temp PO4 NO3 avgsecci avgWentworth avgveg
  avgemerg avgdepth avgvelocity avgwidth AVGDO HabitatComplexity Cichlids
  /ANALYSIS ALL
   /METHOD=WILKS
   /FIN= 3.84
   /FOUT= 2.71
  /PRIORS  EQUAL
   /HISTORY
  /STATISTICS=COEFF TABLE CROSSVALID
  /CLASSIFY=NONMISSING POOLED .
```

Discriminant

[DataSet1]

Analysis Case Processing Summary

Unweighted Cases		N	Percent
Valid		13	68.4
Excluded	Missing or out-of-range group codes	6	31.6
	At least one missing discriminating variable	0	.0
	Both missing or out-of-range group codes and at least one missing discriminating variable	0	.0
	Total	6	31.6
Total		19	100.0

Group Statistics

Cluster		Valid N (listwise) Unweighted	Weighted
1	pH	10	10.000
	Cond	10	10.000
	NH4	10	10.000
	water_temp	10	10.000
	PO4	10	10.000
	NO3	10	10.000
	avg secci	10	10.000
	avg Wentworth	10	10.000
	avg veg	10	10.000
	avg emerg	10	10.000
	avg depth	10	10.000
	avg velocity	10	10.000
	avg width	10	10.000
	AVG DO	10	10.000
	Habitat Complexity	10	10.000
	Cichlids	10	10.000
2	pH	1	1.000
	Cond	1	1.000
	NH4	1	1.000
	water_temp	1	1.000
	PO4	1	1.000
	NO3	1	1.000
	avg secci	1	1.000
	avg Wentworth	1	1.000
	avg veg	1	1.000
	avg emerg	1	1.000
	avg depth	1	1.000
	avg velocity	1	1.000
	avg width	1	1.000
	AVG DO	1	1.000
	Habitat Complexity	1	1.000
	Cichlids	1	1.000
3	pH	2	2.000
	Cond	2	2.000
	NH4	2	2.000
	water_temp	2	2.000
	PO4	2	2.000
	NO3	2	2.000
	avg secci	2	2.000
	avg Wentworth	2	2.000
	avg veg	2	2.000
	avg emerg	2	2.000
	avg depth	2	2.000
	avg velocity	2	2.000
	avg width	2	2.000
	AVG DO	2	2.000
	Habitat Complexity	2	2.000
	Cichlids	2	2.000
Total	pH	13	13.000

Analysis 1
Stepwise Statistics

Variables Entered/Removed[a,b,c,d]

Step	Entered	Wilks' Lambda							
		Statistic	df1	df2	df3	Exact F			
						Statistic	df1	df2	Sig.
1	Habitat Complexity	.448	1	2	10.000	6.161	2	10.000	.018

At each step, the variable that minimizes the overall Wilks' Lambda is entered.

a. Maximum number of steps is 32.

b. Minimum partial F to enter is 3.84.

c. Maximum partial F to remove is 2.71.

d. F level, tolerance, or VIN insufficient for further computation.

Variables in the Analysis

Step		Tolerance	F to Remove
1	Habitat Complexity	1.000	6.161

Variables Not in the Analysis

Step		Tolerance	Min. Tolerance	F to Enter	Wilks' Lambda
0	pH	1.000	1.000	1.847	.730
	Cond	1.000	1.000	.283	.946
	NH4	1.000	1.000	2.820	.639
	water_temp	1.000	1.000	1.243	.801
	PO4	1.000	1.000	.336	.937
	NO3	1.000	1.000	.113	.978
	avg secci	1.000	1.000	.483	.912
	avg Wentworth	1.000	1.000	2.810	.640
	avg veg	1.000	1.000	.352	.934
	avg emerg	1.000	1.000	2.542	.663
	avg depth	1.000	1.000	1.750	.741
	avg velocity	1.000	1.000	.291	.945
	avg width	1.000	1.000	3.557	.584
	AVG DO	1.000	1.000	1.519	.767
	Habitat Complexity	1.000	1.000	6.161	.448
	Cichlids	1.000	1.000	.160	.969
1	pH	.851	.851	.147	.434
	Cond	.530	.530	2.019	.309
	NH4	.982	.982	2.510	.288
	water_temp	.984	.984	1.206	.353
	PO4	.577	.577	.879	.375
	NO3	.737	.737	.922	.372
	avg secci	.921	.921	.332	.417
	avg Wentworth	.857	.857	.638	.392
	avg veg	.767	.767	1.536	.334
	avg emerg	.662	.662	2.212	.300
	avg depth	.941	.941	.371	.414
	avg velocity	.973	.973	.386	.413
	avg width	.392	.392	.507	.403
	AVG DO	.897	.897	1.909	.315
	Cichlids	.997	.997	.133	.435

Wilks' Lambda

Step	Number of Variables	Lambda	df1	df2	df3	Exact F			
						Statistic	df1	df2	Sig.
1	1	.448	1	2	10	6.161	2	10.000	.018

Summary of Canonical Discriminant Functions

Eigenvalues

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	1.232[a]	100.0	100.0	.743

a. First 1 canonical discriminant functions were used in the analysis.

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.448	8.029	2	.018

Standardized Canonical Discriminant Function Coefficients

	Function
	1
Habitat Complexity	1.000

Structure Matrix

	Function
	1
Habitat Complexity	1.000
avg width[a]	-.780
Cond[a]	-.685
PO4[a]	-.650
avg emerg[a]	-.581
NO3[a]	-.513
avg veg[a]	-.483
pH[a]	-.386
avg Wentworth[a]	.378
AVG DO[a]	-.322
avg secci[a]	.281
avg depth[a]	-.243
avg velocity[a]	-.164
NH4[a]	-.133
water_temp[a]	.125
Cichlids[a]	-.055

Pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions
Variables ordered by absolute size of correlation within function.

a. This variable not used in the analysis.

Functions at Group Centroids

Cluster	Function 1
1	.485
2	-.430
3	-2.212

Unstandardized canonical discriminant functions evaluated at group means

Classification Statistics

Classification Processing Summary

Processed		19
Excluded	Missing or out-of-range group codes	0
	At least one missing discriminating variable	0
Used in Output		19

Prior Probabilities for Groups

		Cases Used in Analysis	
Cluster	Prior	Unweighted	Weighted
1	.333	10	10.000
2	.333	1	1.000
3	.333	2	2.000
Total	1.000	13	13.000

Classification Function Coefficients

	Cluster		
	1	2	3
Habitat Complexity	27.634	21.703	10.151
(Constant)	-10.183	-6.702	-2.324

Fisher's linear discriminant functions

Classification Results[b,c]

		Cluster	Predicted Group Membership 1	2	3	Total
Original	Count	1	7	3	0	10
		2	0	1	0	1
		3	0	1	1	2
		Ungrouped cases	2	1	3	6
	%	1	70.0	30.0	.0	100.0
		2	.0	100.0	.0	100.0
		3	.0	50.0	50.0	100.0
		Ungrouped cases	33.3	16.7	50.0	100.0
Cross-validated[a]	Count	1	7	3	0	10
		2	1	0	0	1
		3	0	1	1	2
	%	1	70.0	30.0	.0	100.0
		2	100.0	.0	.0	100.0
		3	.0	50.0	50.0	100.0

a. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

b. 69.2% of original grouped cases correctly classified.

c. 61.5% of cross-validated grouped cases correctly classified.

```
SAVE OUTFILE='F:\research data\stats\spssstepwise\CPUEdiscriminat.sav'
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APPENDIX XI:

Statistics Report: Principal Components Analysis

PCA Seine

Seine Principal Component Analysis: pH, Cond, ammonia, water_temp, phosphate, nitrate

Eigenanalysis of the Correlation Matrix

Eigenvalue	4.9918	3.2921	2.4993	2.1337	1.5949	1.2175	1.0562	0.9327
Proportion	0.238	0.157	0.119	0.102	0.076	0.058	0.050	0.044
Cumulative	0.238	0.394	0.513	0.615	0.691	0.749	0.799	0.844

Eigenvalue	0.8028	0.6208	0.5071	0.3970	0.3303	0.2243	0.1309	0.0918
Proportion	0.038	0.030	0.024	0.019	0.016	0.011	0.006	0.004
Cumulative	0.882	0.912	0.936	0.955	0.970	0.981	0.987	0.992

Eigenvalue	0.0692	0.0520	0.0356	0.0130	0.0071
Proportion	0.003	0.002	0.002	0.001	0.000
Cumulative	0.995	0.997	0.999	1.000	1.000

Variable	PC1	PC2
pH	0.337	0.266
Cond	0.048	0.113
ammonia	-0.063	0.139
water_temp	0.166	0.135
phosphate	0.193	-0.159
nitrate	-0.011	-0.056
avg secci	-0.255	0.283
avg Wentworth	-0.200	0.263
avg veg	-0.032	0.042
avg emerg	0.115	0.017
avg depth	0.101	-0.437
avg velocity	0.038	-0.385
avg width	0.407	-0.088
AVG DO	0.296	0.100
Habitat Complexity	-0.318	0.142
Shannon-Wiener	-0.017	-0.309
Evenness	-0.125	-0.398
Total Numbers	0.405	0.085
Richness	0.299	0.092
CENTRAR	0.247	0.139
Cichlids	0.023	0.179

PCA ES

Principal Component Analysis: pH, Cond, NH4, water_temp, PO4, NO3, avg secci, a

Eigenanalysis of the Correlation Matrix

Eigenvalue	6.0768	3.3491	2.5947	2.1039	1.4473	1.2357	0.9689	0.9028
Proportion	0.289	0.159	0.124	0.100	0.069	0.059	0.046	0.043
Cumulative	0.289	0.449	0.572	0.673	0.742	0.800	0.846	0.889

Eigenvalue	0.5936	0.4563	0.4155	0.3102	0.2393	0.1264	0.0927	0.0515
Proportion	0.028	0.022	0.020	0.015	0.011	0.006	0.004	0.002
Cumulative	0.918	0.939	0.959	0.974	0.985	0.991	0.996	0.998

Eigenvalue	0.0340	0.0016	0.0000	0.0000	-0.0000
Proportion	0.002	0.000	0.000	0.000	-0.000
Cumulative	1.000	1.000	1.000	1.000	1.000

Variable	PC1	PC2
pH	0.248	-0.037
Cond	0.225	-0.261
NH4	0.028	0.032
water_temp	0.060	0.284
PO4	0.275	-0.257
NO3	0.194	-0.039
avg secci	-0.184	0.182
avg Wentworth	-0.242	0.132
avg veg	-0.096	-0.287
avg emerg	0.253	-0.111
avg depth	0.139	-0.092
avg velocity	0.006	-0.392
avg width	0.332	-0.141
AVG DO	0.210	-0.014
Habitat Complexity	-0.346	0.174
Shannon-Wiener	-0.283	-0.353
Evenness	-0.229	-0.265
Total Numbers	0.241	-0.028
Richness	-0.258	-0.344
CENTRAR	-0.232	-0.327
Cichlids	0.020	0.057

APPENDIX XII:

Statistics Report: Stepwise Multiple Regression

ES Stepwise Regression: CENTRAR versus Cichlids, pH, ...

```
  Alpha-to-Enter: 0.15  Alpha-to-Remove: 0.15
Response is CENTRAR on 16 predictors, with N = 57

Step                1         2         3          4          5          6
Constant      0.13253   0.09934   0.18814   -0.63214   -0.87121   -1.07991

avg emerg     -0.0060   -0.0064   -0.0063    -0.0092    -0.0135    -0.0157
T-Value         -2.35     -2.56     -2.62      -3.22      -3.80      -4.41
P-Value         0.023     0.013     0.011      0.002      0.000      0.000

avg velocity               0.24      0.31       0.35       0.35       0.34
T-Value                    2.19      2.75       3.14       3.26       3.24
P-Value                   0.033     0.008      0.003      0.002      0.002

AVG DO                            -0.0196    -0.0373    -0.0395    -0.0478
T-Value                             -2.21      -2.83      -3.07      -3.70
P-Value                             0.031      0.007      0.003      0.001

pH                                             0.120      0.132      0.160
T-Value                                         1.79       2.01       2.48
P-Value                                        0.079      0.050      0.017

Cond                                                    0.00031    0.00042
T-Value                                                    1.96       2.64
P-Value                                                   0.055      0.011

Cichlids                                                            -0.099
T-Value                                                              -2.24
P-Value                                                              0.030

S               0.184     0.178     0.172      0.168      0.164      0.158
R-Sq             9.10     16.51     23.56      28.00      33.05      39.16
R-Sq(adj)        7.45     13.41     19.24      22.46      26.49      31.86
Mallows Cp       30.5      25.7      21.3       19.2       16.5       12.9

Step                7
Constant       -1.325

avg emerg     -0.0177
T-Value         -5.01
P-Value         0.000

avg velocity     0.35
T-Value          3.47
P-Value         0.001

AVG DO         -0.047
T-Value         -3.81
P-Value         0.000

pH              0.186
T-Value          2.95
P-Value         0.005

Cond          0.00056
T-Value          3.38
```

P-Value	0.001
Cichlids	-0.116
T-Value	-2.68
P-Value	0.010
NO3	-0.58
T-Value	-2.25
P-Value	0.029
S	0.152
R-Sq	44.87
R-Sq(adj)	37.00
Mallows Cp	9.7

Stepwise Regression: H versus Cichlids, pH, ...

Alpha-to-Enter: 0.15 Alpha-to-Remove: 0.15

Response is H on 16 predictors, with N = 57

Step	1	2	3	4	5	6
Constant	0.5915	0.2907	1.7861	2.4100	2.7460	1.9401
avg velocity	0.74	0.83	0.68	0.63	0.58	0.91
T-Value	2.91	3.42	2.71	2.57	2.36	3.16
P-Value	0.005	0.001	0.009	0.013	0.022	0.003
Habitat Complexity		0.57	0.60	0.35		
T-Value		2.77	2.96	1.46		
P-Value		0.008	0.005	0.151		
water_temp			-0.052	-0.066	-0.070	-0.052
T-Value			-1.90	-2.38	-2.51	-1.81
P-Value			0.063	0.021	0.015	0.076
avg emerg				-0.0120	-0.0173	-0.0182
T-Value				-1.87	-3.21	-3.47
P-Value				0.067	0.002	0.001
avg secci						0.0042
T-Value						2.05
P-Value						0.045
S	0.409	0.386	0.377	0.369	0.372	0.362
R-Sq	13.31	24.11	28.95	33.44	30.71	35.89
R-Sq(adj)	11.73	21.30	24.93	28.32	26.79	30.96
Mallows Cp	18.3	11.4	9.4	7.7	7.9	5.7

Step	7	8
Constant	1.0686	-0.2010
avg velocity	1.05	1.23
T-Value	3.67	4.80
P-Value	0.001	0.000
Habitat Complexity		
T-Value		
P-Value		
water_temp	-0.039	
T-Value	-1.38	
P-Value	0.173	

avg emerg	-0.0284	-0.0283
T-Value	-4.07	-4.01
P-Value	0.000	0.000
avg secci	0.0059	0.0069
T-Value	2.75	3.46
P-Value	0.008	0.001
Cond	0.00077	0.00087
T-Value	2.13	2.45
P-Value	0.038	0.018
S	0.350	0.353
R-Sq	41.13	38.92
R-Sq(adj)	35.36	34.22
Mallows Cp	3.4	3.2

Stepwise Regression: E versus Cichlids, pH, ...

Alpha-to-Enter: 0.15 Alpha-to-Remove: 0.15

Response is E on 16 predictors, with N = 57

Step	1	2	3	4	5
Constant	0.3478	1.2935	1.5932	1.4803	1.3832
Habitat Complexity	0.37	0.40	0.27	0.44	0.62
T-Value	3.21	3.56	2.05	2.85	3.32
P-Value	0.002	0.001	0.046	0.006	0.002
water_temp		-0.033	-0.040	-0.042	-0.046
T-Value		-2.30	-2.72	-2.89	-3.21
P-Value		0.025	0.009	0.006	0.002
avg emerg			-0.0063	-0.0100	-0.0102
T-Value			-1.76	-2.52	-2.61
P-Value			0.085	0.015	0.012
PO4				0.057	0.052
T-Value				1.99	1.83
P-Value				0.051	0.073
avg width					0.0115
T-Value					1.66
P-Value					0.102
S	0.220	0.212	0.208	0.202	0.199
R-Sq	15.81	23.34	27.56	32.71	36.18
R-Sq(adj)	14.28	20.50	23.46	27.54	29.92
Mallows Cp	16.2	12.0	10.5	8.3	7.4

Stepwise Regression: Total No versus Cichlids, pH, ...

Alpha-to-Enter: 0.15 Alpha-to-Remove: 0.15

Response is Total No on 16 predictors, with N = 57

Step	1	2	3	4	5	6
Constant	9.942	7.382	-1.426	-2.256	-3.159	-29.805
Habitat Complexity	-9.3	-6.2	-0.9			
T-Value	-4.08	-2.34	-0.29			

P-Value	0.000	0.023	0.775			
avg emerg		0.143	0.241	0.255	0.270	0.202
T-Value		2.04	3.32	4.73	5.14	3.83
P-Value		0.046	0.002	0.000	0.000	0.000
avg depth			4.1	4.3	5.3	6.9
T-Value			3.07	3.99	4.66	5.94
P-Value			0.003	0.000	0.000	0.000
NO3					-13.4	-21.9
T-Value					-2.18	-3.51
P-Value					0.034	0.001
pH						3.3
T-Value						3.24
P-Value						0.002
S	4.29	4.18	3.88	3.85	3.72	3.43
R-Sq	23.25	28.75	39.48	39.38	44.37	53.72
R-Sq(adj)	21.85	26.11	36.05	37.14	41.22	50.16
Mallows Cp	52.5	46.9	34.2	32.3	27.4	16.6

Step	7	8	9
Constant	-50.26	-60.73	-58.59
Habitat Complexity			
T-Value			
P-Value			
avg emerg	0.147	0.115	0.118
T-Value	2.76	2.18	2.32
P-Value	0.008	0.034	0.024
avg depth	9.2	10.6	10.1
T-Value	6.70	7.44	7.23
P-Value	0.000	0.000	0.000
NO3	-23.3	-29.2	-28.1
T-Value	-3.95	-4.78	-4.73
P-Value	0.000	0.000	0.000
pH	5.2	6.0	5.7
T-Value	4.43	5.14	5.06
P-Value	0.000	0.000	0.000
avg secci	0.060	0.066	0.057
T-Value	2.79	3.17	2.79
P-Value	0.007	0.003	0.007
NH4		7.2	8.2
T-Value		2.47	2.84
P-Value		0.017	0.006
Cichlids			1.62
T-Value			2.03
P-Value			0.047
S	3.22	3.07	2.98
R-Sq	59.87	64.23	67.02
R-Sq(adj)	55.93	59.94	62.31
Mallows Cp	10.1	6.1	4.3

Stepwise Regression: Richness versus Cichlids, pH, ...

```
  Alpha-to-Enter: 0.15  Alpha-to-Remove: 0.15

Response is Richness on 16 predictors, with N = 57

Step              1       2       3       4        5        6
Constant     3.5176  3.3281  3.5843  1.9745  -0.6344  -1.0434

avg veg      0.0283  0.0230  0.0242  0.0185   0.0076
T-Value        2.97    2.30    2.44    1.82     0.72
P-Value       0.004   0.026   0.018   0.074    0.473

avg velocity            1.9     2.0     2.2      4.3      4.8
T-Value                1.58    1.66    1.87     3.12     4.03
P-Value               0.119   0.103   0.068    0.003    0.000

avg emerg                    -0.040  -0.081   -0.117   -0.125
T-Value                       -1.60   -2.44    -3.40    -3.80
P-Value                       0.116   0.018    0.001    0.000

Cond                                 0.0032   0.0052   0.0058
T-Value                                1.83     2.85     3.51
P-Value                               0.073    0.006    0.001

avg secci                                     0.0264   0.0294
T-Value                                         2.58     3.14
P-Value                                        0.013    0.003

S              1.83    1.80    1.78    1.74     1.65     1.64
R-Sq          13.86   17.68   21.46   26.22    34.72    34.05
R-Sq(adj)     12.29   14.63   17.01   20.55    28.31    28.97
Mallows Cp     13.7    12.8    11.8    10.2      5.6      4.1

Step              7
Constant    -0.9191

avg veg
T-Value
P-Value

avg velocity    4.7
T-Value        3.97
P-Value       0.000

avg emerg    -0.128
T-Value       -3.95
P-Value       0.000

Cond         0.0064
T-Value        3.87
P-Value       0.000

avg secci    0.0246
T-Value        2.56
P-Value       0.013

NO3            -4.6
T-Value       -1.73
P-Value       0.089

S              1.61
R-Sq          37.71
```

R-Sq(adj)	31.60
Mallows Cp	3.3

Stepwise Regression: Cichlids versus CENTRAR, pH, ...

Alpha-to-Enter: 0.15 Alpha-to-Remove: 0.15

Response is Cichlids on 16 predictors, with N = 57

Step	1	2	3	4
Constant	0.3825	0.6568	0.3030	0.4052
AVG DO	-0.045	-0.043	-0.045	-0.055
T-Value	-1.75	-1.68	-1.78	-2.20
P-Value	0.085	0.098	0.081	0.032
NH4		-0.70	-0.72	-0.95
T-Value		-1.63	-1.71	-2.24
P-Value		0.108	0.093	0.029
Cond			0.00060	0.00082
T-Value			1.69	2.27
P-Value			0.096	0.027
avg veg				-0.0056
T-Value				-1.99
P-Value				0.051
S	0.517	0.510	0.501	0.488
R-Sq	5.29	9.75	14.39	20.47
R-Sq(adj)	3.57	6.41	9.55	14.35
Mallows Cp	20.6	19.1	17.5	14.8

Seine Data:

Stepwise Regression: CENTRAR versus pH, Cond, ...

Alpha-to-Enter: 0.15 Alpha-to-Remove: 0.15

Response is CENTRAR on 16 predictors, with N = 32

Step	1	2	3	4	5	6
Constant	-0.2854	-0.1313	-0.8316	-2.7909	-2.7298	-3.6210
avg width	0.141	0.195	0.201	0.256	0.244	0.250
T-Value	3.11	4.20	4.83	5.15	4.99	5.28
P-Value	0.004	0.000	0.000	0.000	0.000	0.000
phosphate		-0.42	-0.43	-0.39	-0.41	-0.38
T-Value		-2.62	-3.00	-2.83	-3.07	-2.91
P-Value		0.014	0.006	0.009	0.005	0.008
Cond			0.00067	0.00083	0.00076	0.00081
T-Value			2.86	3.46	3.20	3.50
P-Value			0.008	0.002	0.004	0.002
Habitat Complexity				2.2	2.0	1.9
T-Value				1.87	1.78	1.71
P-Value				0.073	0.087	0.100
avg emerg					0.040	0.041
T-Value					1.64	1.73
P-Value					0.113	0.096

ammonia						2.1
T-Value						1.66
P-Value						0.110
S	1.79	1.63	1.46	1.40	1.36	1.32
R-Sq	24.33	38.83	52.66	58.07	62.00	65.75
R-Sq(adj)	21.81	34.61	47.58	51.85	54.69	57.53
Mallows Cp	34.1	24.2	14.9	12.4	11.2	10.1

Stepwise Regression: Shannon-Wiener versus pH, Cond, ...

Alpha-to-Enter: 0.15 Alpha-to-Remove: 0.15

Response is Shannon-Wiener on 16 predictors, with N = 32

Step	1	2	3	4	5
Constant	0.8065	2.7822	4.7292	5.0495	5.1290
avg emerg	0.0128	0.0153	0.0200	0.0192	0.0218
T-Value	2.29	2.98	4.22	4.35	4.76
P-Value	0.029	0.006	0.000	0.000	0.000
pH		-0.262	-0.582	-0.627	-0.632
T-Value		-2.75	-4.44	-5.08	-5.27
P-Value		0.010	0.000	0.000	0.000
AVG DO			0.091	0.102	0.100
T-Value			3.16	3.73	3.76
P-Value			0.004	0.001	0.001
nitrate				-0.070	-0.074
T-Value				-2.33	-2.52
P-Value				0.027	0.018
Cichlids					-0.0105
T-Value					-1.61
P-Value					0.119
S	0.327	0.296	0.259	0.240	0.233
R-Sq	14.92	32.53	50.25	58.58	62.34
R-Sq(adj)	12.08	27.87	44.92	52.44	55.09
Mallows Cp	23.8	15.1	6.3	3.2	2.9

Stepwise Regression: Evenness versus pH, Cond, ...

Alpha-to-Enter: 0.15 Alpha-to-Remove: 0.15

Response is Evenness on 16 predictors, with N = 32

Step	1	2	3	4
Constant	1.527	2.202	2.557	2.583
pH	-0.148	-0.258	-0.319	-0.320
T-Value	-3.59	-4.57	-6.17	-6.34
P-Value	0.001	0.000	0.000	0.000
AVG DO		0.033	0.045	0.044
T-Value		2.62	3.96	3.95
P-Value		0.014	0.000	0.000
avg emerg			0.0063	0.0074
T-Value			3.38	3.78
P-Value			0.002	0.001

Cichlids				-0.0043
T-Value				-1.55
P-Value				0.134
S	0.130	0.119	0.102	0.0995
R-Sq	30.11	43.46	59.82	63.09
R-Sq(adj)	27.78	39.56	55.52	57.62
Mallows Cp	29.3	20.4	8.9	8.3

Stepwise Regression: Total Numbers versus pH, Cond, ...

Alpha-to-Enter: 0.15 Alpha-to-Remove: 0.15

Response is Total Numbers on 16 predictors, with N = 32

Step	1	2	3	4	5	6
Constant	-190.2	-1402.1	-1444.7	-1433.0	-1538.4	-1665.6
avg width	23.8	15.4	15.4	8.3	4.7	
T-Value	6.50	4.02	4.35	2.16	1.12	
P-Value	0.000	0.000	0.000	0.040	0.273	
pH		175	176	203	228	258
T-Value		3.68	4.00	5.15	5.68	8.46
P-Value		0.001	0.000	0.000	0.000	0.000
Cichlids			6.8	11.1	10.9	11.6
T-Value			2.39	3.90	3.98	4.33
P-Value			0.024	0.001	0.000	0.000
avg secci				-2.67	-2.61	-3.08
T-Value				-3.11	-3.18	-4.31
P-Value				0.004	0.004	0.000
avg Wentworth					-57	-73
T-Value					-1.84	-2.67
P-Value					0.078	0.013
S	143	120	112	97.6	93.5	94.0
R-Sq	58.44	71.69	76.49	82.70	84.69	83.95
R-Sq(adj)	57.06	69.74	73.97	80.14	81.74	81.57
Mallows Cp	32.2	15.0	10.1	3.1	2.2	1.2

Stepwise Regression: Richness versus pH, Cond, ...

Alpha-to-Enter: 0.15 Alpha-to-Remove: 0.15

Response is Richness on 16 predictors, with N = 32

Step	1	2	3
Constant	5.945	6.090	5.644
avg width	0.350	0.367	0.335
T-Value	3.39	3.86	3.58
P-Value	0.002	0.001	0.001
nitrate		-1.16	-1.03
T-Value		-2.54	-2.31
P-Value		0.017	0.029
avg emerg			0.113
T-Value			1.80
P-Value			0.083

S	4.05	3.72	3.59
R-Sq	27.68	40.80	46.91
R-Sq(adj)	25.27	36.72	41.22
Mallows Cp	14.1	8.5	6.9

Stepwise Regression: Cichlids versus Month, CENTRAR, ...

Alpha-to-Enter: 0.15 Alpha-to-Remove: 0.15

Response is Cichlids on 14 predictors, with N = 320

Step	1	2	3	4	5	6
Constant	-1.627	-2.618	-9.478	13.955	1.110	1.002
Richness	1.20	0.98	0.81	1.09	1.04	1.11
T-Value	5.06	4.13	3.35	4.20	3.99	4.21
P-Value	0.000	0.000	0.001	0.000	0.000	0.000
Cond		0.00223	0.00220	0.00201	0.00196	0.00271
T-Value		3.82	3.82	3.50	3.42	3.66
P-Value		0.000	0.000	0.001	0.001	0.000
alkalinity			0.043	0.050	0.065	0.063
T-Value			3.07	3.57	3.84	3.76
P-Value			0.002	0.000	0.000	0.000
pH				-3.4	-4.5	-4.7
T-Value				-2.79	-3.19	-3.34
P-Value				0.006	0.002	0.001
water_temp					0.66	0.71
T-Value					1.53	1.66
P-Value					0.126	0.098
salinity						-0.73
T-Value						-1.60
P-Value						0.110
S	11.4	11.2	11.0	10.9	10.9	10.9
R-Sq	7.44	11.52	14.08	16.15	16.78	17.45
R-Sq(adj)	7.15	10.96	13.26	15.09	15.45	15.87
Mallows Cp	30.0	16.8	9.2	3.5	3.1	2.6
PRESS	41879.0	40210.3	39552.4	38862.8	38744.5	38491.9
R-Sq(pred)	6.36	10.10	11.57	13.11	13.37	13.94