Species Diversity and Condition of the Fish Community During a Drought in Congaree National Park

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Abstract:

From the period including 1999 through 2002, the South Carolina Department of Natural Resources (SCDNR) completed a total of 59 fish surveys under a cooperative agreement with Congaree National Park (CONG). Fifty surveys were completed from 33 sites within the CONG boundary and nine surveys were completed from nine sites external to the park boundary. This effort established baseline data to characterize the condition of the fish community in the park. Through this inventory, the goal was to accomplish two main objectives:

1. Inventory the fish species within CONG.

2. Define the relative condition of the fish community within the park.

Under normal meteorological conditions, the CONG floods periodically throughout the year. During this sampling effort, the CONG experienced extreme drought conditions and flooding events were rare. The dry conditions enabled sampling in areas that would normally not be suitable. Additionally, we were able to observe the fish community during natural degradation in fish habitat brought on by the drought.

By using clustering and ordination techniques we were able to describe three distinctively separate fish communities in the swamp and correlate these groups with specific habitat conditions. The resulting information was used to develop a model that predicts the expected fish community given specific habitat conditions during a drought. With further testing under non-drought conditions, this model could be modified for use

as a long term monitoring tool to measure the condition of the streams in the Congaree floodplain.

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Introduction:

Prior to this study, there was limited information on the fish community in Congaree National Park (CONG). The majority of information came from two studies conducted between 1995 and 1998. In 1996, the South Carolina Department of Natural Resources (SCDNR) surveyed three CONG stream sites and two oxbow lakes (Bulak 1997). Between 1995 and 1998, the U.S. Geological Survey (USGS) surveyed four streams on and adjacent to CONG (Maluk and Abrahamsen 1999). These two limited surveys identified 34 species of fish within CONG.

Maluk and Abrahamsen (1999), attempted to characterize the condition of the CONG streams by calculating an index of biotic integrity (IBI) that was developed for the Piedmont ecoregion of South Carolina. They concluded that three streams were in poor condition and the fourth, Cedar Creek, was in fair to poor condition. The streams of CONG bear little resemblance to the Piedmont ecoregion of SC. Numerous studies have cautioned against extrapolating IBI metrics into other ecoregions without modifying them to suit local fauna and habitat (Daniels et al. 2002; Schleiger 2000; Hocutt 1981; and Goldstein et al. 1994). As such, one would not expect the stream condition in the CONG to be accurately characterized by an IBI designed for the Piedmont. A method for characterizing the condition of the CONG fishery community was needed that would accurately account for the local habitat and fauna.

The objective of this sampling was to comprehensively inventory the fish community of the CONG using a sampling strategy that would also define the relative condition of the streams. This study expands the existing CONG fish inventory and attempts to quantify the condition of the studied streams. In order to obtain samples from a sufficient number of sites to fully characterize the fish community, samples were collected from broad temporal, spatial and habitat ranges within the CONG from 1999 through 2002. The sampling locations included ponds, oxbow lakes, guts, sloughs, flats and streams. Sites near the Congaree River were selected to enable the collection of riverine species that may migrate into the park. The majority of samples were scheduled during the summer months to take advantage of low water levels, however, some were collected in the spring to enable the capture of any early season riverine spawning fish that may use the CONG as a refuge.

Study area

The CONG is located approximately thirty miles southeast of Columbia, South Carolina. It contains some of the least disturbed habitat left in the Southeastern Floodplains and Low Terraces ecoregion (Figure 1). The park is recognized as an International Biosphere Reserve, National Natural Landmark, Wilderness Area, and "Globally Important Bird Area." It features some of the tallest trees in the east and one of the highest forest canopies in the world. The park encompasses over 22,200 acres with about 10,000 acres of old-growth forest making it the largest intact tract of old-growth bottomland hardwood forest in the United States.

The northern boundary of the park receives water from 5 tributary basins. Four of the basins extend from the Sand Hills, through the Atlantic Southern Loam Plains, before transitioning into the Southeastern Floodplains and Low Terraces ecoregion. These basins collect water to form Myers Creek, Dry Branch, Cedar Creek, and Tom's

Creek/McKenzie Creek. The fifth unnamed basin is a small basin that originates in the Atlantic Southern Loam Plains and contributes little water to the park. The Congaree River forms the southern boundary of the park, which collects water from the entire Congaree River basin including the Saluda River, Enoree River, Tyger River, Pacolet River and the Broad River. In a study of the Congaree River water level records from 1973-1982, river water inundated the parks floodplain an average of 11 times per year; the river reached bankfull flow at the park's western boundary an average of 5 times per year; and river water inundated as much as 90% of the Park approximately once per year (Patterson, et al. 1985). The park is characterized by features typical of its ecoregion including a large, sluggish river; sandy, silty, low gradient streams; and oxbow lakes, ponds and swamps (Griffith et al. 2002). Bottomland hardwood forests and cypress-gum swamps are the principal habitats found in CONG. CONG has an interconnected network of streams, guts, sloughs and oxbow lakes that connect with the Congaree River during high water and flood events. When floodwaters recede, many of the streams and guts loose their connection to other sites in the network and cease to flow or flow very slowly. Other CONG streams continue to flow well even through drought conditions. Consequently, the habitat available to fish in CONG varies greatly.

Methods:

Site selection and sampling

To choose survey locations that would comprehensively sample the waters of CONG, regional maps, geographic information systems (GIS), and local experts were consulted. Initially, a GIS was used to designate potential sampling locations within and around CONG based on proximity to CONG, ecoregion, and type (stream, slough or lake). Suitability for sampling was generally based on site visits. Locations that were too deep were either considered unsuitable or placed on a wait list until the water level dropped enough to effectively sample. Due to the difficult terrain and extensive hiking involved, some of the sites were not visited before sampling. In those cases, suitability was determined upon arrival.

Some sites were sampled repeatedly over the course of the three-year study to test the precision of the sampling technique and to determine the extent of temporal variation. Sites that were repeatedly sampled were from varying habitat types and locations within the CONG. A number of out-of-park sampling sites were included as reference points. These sites were selected to help establish the expected structure of the CONG fish community. Figure 1 is a map depicting all of the fish sampling locations. A complete list of sample sites, locations and types is available in Appendix 1.

Streams were sampled using a multi-pass depletion method. A 100-meter stream segment that contained representative habitats was delineated. Block nets with a mesh size of no larger than 0.635 centimeters were placed at both the upstream and downstream boundaries of the stream segment. Depending on the size of the stream, one, two or three, Smith Root battery-powered, 24 volt, backpack, electrofishing units were used to make three consecutive upstream passes through the sampling reach. Generally, where new species were found on the third pass, a fourth pass was made. One electrofishing unit was used where the stream was less than 3 meters wide while two units were used where the stream was between 3 and 6 meters. Three units were used for streams wider than 6 meters or where an adequate sample would not be obtained with only two units. To minimize size and species selectivity bias associated with electrofishing, we established standard frequency and pulse-width settings at 60Hz and 6ms, respectively. The low conductivity conditions associated with CONG streams usually required relatively high voltage settings of between 600 and 900 volts to provide adequate current to effectively stun the fish. An attempt was made to collect and numerate all stunned fish. Where possible, collected fish were field identified to species, measured and returned to the water alive. Where field identifications were uncertain, the fish were preserved in 10% buffered formalin and identified in a laboratory using appropriate keys (Rohde 1999). Selected specimens were sent to regional experts in fish taxonomy to confirm identifications. Representatives of each collected species were saved in a reference collection.

To help ensure that the inventory of CONG would be comprehensive, the guts, sloughs, and lakes of the CONG were also sampled. These samples were not included in the quantitative community assessment of the streams. In most cases, one or more backpack electrofishers were used to sample these locations. An effort was made to make at least one pass through the entire lake, gut or slough. Where the water body was either too deep or too large to make a complete pass with the backpack electrofisher, a segment was selected that was at least 300 meters and included all the representative habitat types. An effort was made to collect and identify all fish to species.

The oxbow lakes present in the park were formed as meanders in the Congaree River were cut off from the main river channel as it found new pathways through its floodplain. Two of these isolated portions of the river resulted in Weston Lake (4 acres) and Wise lake (1.2 acres). These two lakes, previously surveyed by Bulak in 1996, were surveyed again during this study. Weston and Wise lakes were sampled using a boatmounted electrofisher according to the methodology employed by Bulak (1997). This unit consisted of a 12 foot Johnboat equipped with a Homelite 5HP 2500W generator and Smith-Root model 1.5 KVA-83 electrofisher. During electrofishing, there was one boat operator and one netter. Uninterrupted direct current (DC) was applied to the water at 566 volts resulting in a current of approximately 2 amps. To comply with the wilderness requirements in the CONG, the boat was paddled around the entire perimeter of both lakes while shocking along the margins. An attempt was made to collect, measure and identify all fish. Identified fish were returned alive to the lake.

Standard physical, chemical and biological information was collected at each sampling location (Table 1). The average stream width was determined by measuring the wetted width at the downstream limit of the sample reach and then every 25 m to the upstream extent of the sample reach. All five measurements were averaged to determine the overall average stream width. The average depth was determined by taking three depth measurements along each transect where wetted width was measured. All fifteen observations were averaged to determine the overall average stream depth. The Environmental Protection Agency's (EPA) Rapid Bioassessment Visual Estimation Technique was used to determine the condition of the stream habitat (Barbour 1999). A categorical suitability and condition index was also assigned to each sited based on a visual estimation. A high condition value corresponded to streams that appeared to have good fish habitat, water quality and physical characteristics. Streams that appeared like they would be sampled effectively with our equipment were given high suitability ratings. Unsuitable sites were given a suitability value of zero and were not used in the condition analysis.

Data analysis

To facilitate data entry, storage, and retrieval, all data were entered into an Access™ database. At stream sites where the quantitative depletion sampling technique was used, we compiled a matrix of the number of individuals of each species collected at each site. To lessen any potential bias in the analysis caused by rare species, fish that were collected at only one site were removed from the analysis. Additionally, three sites that were not within the CONG's ecoregion were also removed. PC-ORD software version 4.25 was used to perform the subsequent matrix calculations, groupings and analysis (McCune 1999).

Some of the grouping analysis required that species be classified by tolerance to pollution. We followed the North Carolina Department of Environment and Natural Resources (NCDENR 2001) classification scheme.

To group sites into hierarchical classification groups based on the similarity of their fauna, a cluster analysis was performed (McCune 2002; Kwak in press). A fourth root power transformation ($b = x_{ij}^{0.25}$; where b is the species matrix and x is the abundance of species j in sample unit i) was performed on the species matrix to reduce the effect that large differences in fish abundance between samples may have on the analysis (Clarke 1993). The Sørensen distance equation was utilized to calculate the similarity. The method used for group linking was the flexible beta method (beta = -0.15). Groups were classified as distinct if an adjacent cluster in the dendrogram retained less than 25% of its information. To facilitate interpretation, the cluster analysis dendrogram was coded to illustrate the separate groupings.

An indicator species analysis was performed to assist in describing the faunal makeup of each classification group. Because this method relies partly on the relative number of individuals at each sample site and a matrix transformation would reduce this value, the matrix used for the indicator species analysis included all species and was not transformed. Indicator values were calculated using the method of Dufrene and Legendre (Dufrene, M. and P. Legendre. 1997). To evaluate the statistical significance of the maximum indicator value recorded for any given species, a Monte Carlo test was performed ($p = 0.05$). A species was used as an indicator of a community when its observed indicator value was greater than 50 and statistically significant.

We also used the non-metric multidimensional scaling (NMS) method (Clarke 1993) to ordinate the CONG samples. NMS is an ordination method that is well suited to data that are non-normal or are arbitrary, discontinuous, or on otherwise questionable scales (McCune 1999). Therefore, it is often suitable for ecological data analysis. As in the cluster analysis, the matrix was transformed and the Sørensen distance measure was used. To minimize the likelihood of the NMS being caught in local minima and failing to find the best solution (minimum stress), the NMS was given a starting configuration that was the result of a detrended correspondence analysis (DCA) on the same matrix (Hill and Gauch 1980). One hundred iterations were run to calculate the stability of the solution. The stability criterion, or the standard deviation in stress over the last 10 iterations was set at 0.0001. To determine the number of dimensions (axes) to use for the final configuration, the final stress was plotted against the number of dimensions. A randomized "null model" version of the data set was used for comparison. The number of axes selected was based on the point at which there was little improvement to the model by adding higher dimensions. To highlight the similarity between the cluster analysis groupings and the ordination, the resulting NMS solution was plotted in two-dimensional space and coded to match the groups determined through the cluster analysis.

A habitat matrix was used to facilitate the correlation of the NMS ordination with environmental and habitat variables. A preliminary analysis found that some of the measured habitat variables, such as conductivity and specific conductivity were highly correlated with each other. Where two variables were highly correlated, one was discarded. Each habitat variable was then correlated to each of the two axes to better characterize the two axes in terms of habitat. Additionally, each species in the species matrix was correlated against the NMS ordination values for both axis 1 and axis 2.

To develop a condition assessment tool, the results of the cluster analysis and NMS ordination were brought together with discriminant analysis (DA) to design a model that predicts community composition based on the environmental characteristics measured in CONG (Ludwig and Reynolds 1988). Where the predicted communities do not match the observed communities there is reason to believe that an additional disturbance has impacted the site. An outlier (Group 4) was eliminated from the DA as it only contained one site. This DA analysis was completed using MINITAB® v13.2[1]. The groups assigned through the cluster analysis (Group 1, 2 and 3) were used for the

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[1] MINITAB® is a registered trademark of Minitab Inc.

grouping classifications in the DA and the measured habitat variables were used as the predictors.

Results:

A total of 56 species of fish were collected within the CONG. Fifty-five species were collected in the park's streams, guts and sloughs and 27 in the ponds and lakes (Table 2). Thirty-three distinct locations were sampled within CONG (Figure 1, Appendix 1). Comparisons with Bulak (1997) showed that 24 species had not been previously reported in the park. During the entire project, a total of 59 species were collected from 59 samples at 42 locations, including 9 streams outside the CONG boundary.

Using cluster analysis and a 25% similarity cut-off value, three main fish communities were identified within CONG (Figure 2). The group 1 community was the most distinct. The group 2 and 3 communities were more similar to each other than they were to group 1, yet they were still distinct. A fourth group, consisting of a single sample, was also identified using the cluster analysis.

In all but one instance where a site was sampled more than once over the course of this study, cluster analysis grouped those sites close to each other (Figure 2). For example, site 101 (Dry Branch) was sampled three times; once in 2001 and twice in 2002. All three of these surveys grouped very close together with more than 90% of the information remaining between them (Sørensen method). This is an indication that sampling was efficient and temporal variation during this time period was low. The Cedar Creek near the Congaree River site (Site 133) was the exception because the 2001 sample did not cluster together with the 2002 sample from the same site. Assuming similar sampling efficiency, this variation indicates that the temporal variation at this one site was high.

An NMS ordination grouped the communities into similar groups as were found with cluster analysis (Figure 3). The stress versus dimensions analysis resulted in a recommendation for a two dimensional analysis. The final two-dimensional ordination yielded a solution with a final stress of 14.9. The two ordination axes together explained 88.4% of the variation in the dissimilarity matrix, with axis 1 accounting for 52% and axis 2 for 36.5% of variance in ordination scores. Monte Carlo simulations indicated that each of the dimensions obtained in the analysis was significant at the $p = 0.05$ level.

Specific conductivity, flow and dissolved oxygen (DO) were significant predictors of the ordination axes (Table 3). The DO concentration in the water, for example, was positively correlated ($r = 0.729$) with axis 1 (Figure 4). Similarly, specific conductance was negatively correlated ($r = -0.569$) with axis 1 and is positively correlated ($r = 0.5$) with axis 2 (Figure 5). Unique combinations of conductivity, flow, and DO helped to explain the main fish community types (Table 4).

Community group 1 sites were characterized by relatively low flows and dissolved oxygen, which likely resulted from a lack of connection to the flowing stream network. Under normal hydrological conditions, regular flooding would re-connect some of these sites to the stream network. Under the drought conditions persistent during the sampling period, all of these sites were experiencing much lower than usual flows. Group 1 clustered all five of the Dry Branch sites and its connectors together (Sites 101, 132 and 116). Also clustered together into group 1 were the very low and no-flow streams (Sites 003, 009, 105, 111, 118, 119, 121, 122, 129 and 133). Interestingly, when site 133 was still flowing in 2001, it clustered with group 2. In 2002, site 133 had almost dried up and clustered into group 1 with the other low and no flow streams. Indicator species analysis determined that the Group 1 indicator species were Flier (*Centrarchus macropterus*, FLR), Eastern mudminnow (*Umbra pygmaea*, EMM), Golden shiner (*Notemigonus crysoleucas*, GLS), and Banded Pygmy sunfish (*Elassoma zonatum*, BPS). Excluding the outlier group 4 site, this group had the highest percentage of fish that are tolerant to harsh conditions (Table 5). Using this information, we characterized this group as the FLR/EMM community.

Community group 2 sites were found to be comprised largely of relatively faster flowing, deeper streams like Cedar Creek. All twelve samples from five separate locations along Cedar Creek were clustered into this group (Sites 102, 108, 110, 112 and 120). Also grouped very close to the Cedar Creek sites in this group were two out-of-park sites that closely resembled Cedar Creek's flow and morphology (Sites 002 and 007). All of the remaining sites in group 2 were flowing and predominantly larger, deeper streams (Sites 107, 127, 128, 131 and 133). The only exception was site 131, which was not flowing when sampled. The indicator fish species for group 2 sites were the Tesselated darter (*Etheostoma olmstedi*, TSD), Largemouth bass (*Micropterus salmoides*, LMB), and the Redear sunfish (*Lepomis microlophus*, RES). We characterized this group as the TSD/LMB/RES community.

Community group 3 included five samples from three locations (Sites 004, 008 and 104). Sites 004 and 104 were both in Tom's Creek, one in the park and one outside the park's boundary. The sample from site 008 was in Tavern Creek, outside the park's boundary. Both Tom's and Tavern Creeks were similar in morphology and fish habitat. Group 3 sites were all located near the transition from the bluff to the swamp and were characterized by relatively firm, sandy bottoms with high flow. The substrate was distinct from the silt and mud that often predominated other sites. Site 103, located further downstream on Tom's Creek, clustered with Group 1 sites and not with the rest of the Tom's Creek and group 3 sites. Site 103 is in a larger, slower moving section of Tom's Creek. The indicator fish species that dominated the group 3 sites were the Sailfin shiner (*Pteronotropis hypselopterus*, SFS), Dusky shiner (*Notropis cummingsae*, DKS), Spotted sunfish (*Lepomis punctatus*, SOS), and the Dollar sunfish (*Lepomis marginatus*, DSF). The fish that made this community unique have been used to label this group as the SFS/DKS community.

Community group 4 was considered an outlier in the cluster analysis dendrogram. It consisted of a single sample at site 113 that only yielded 4 species. Those species were the yellow bullhead, largemouth bass, pirate perch and mosquitofish. The average stream sample contained 16 species of fish. Site 113 was located within the CONG on McKenzie Creek; a small and shallow stream located near the bluff that was flowing at the time of sampling. McKenzie Creek had low DO and a relatively high conductivity. The land-use practices upstream include farming and grazing. A broiler poultry facility is located outside the CONG adjacent to McKenzie Creek. Apparently, upstream anthropogenic factors have impacted this site and have most likely degraded this stream.

Because the indicator species analysis described the faunal makeup for each community group, we would expect the indicator species to cluster together when plotted on the NMS ordination axes. Figure 6 shows a plot of species on the NMS axes. Each of the indicator species cluster with their respective groups providing further support for the indicator species analysis. This illustrates how the species relate to the two axes and supports the hypothesis that there are distinctive communities of fish within the CONG.

Discriminant analysis (DA) was used to develop a function to predict faunal group from temperature, DO, average stream width, and specific conductivity. The DA function predicted community group with an accuracy of 90.7%. The DA function was most accurate at predicting Group 3 sites (100%). Group 2 sites were accurately predicted in 95.2% of cases and Group 1 sites were the least predictable with 82.4% predicted correctly. Using this model to predict faunal group from habitat, a total of 4 samples were misclassified (103-14, 116-28, 122-29 and 131-23).

Discussion:

Through this comprehensive survey of the fishery community, we were able to develop an extensive inventory of the fish fauna in the CONG that included 56 of the states 142 known freshwater fish species (Rohde et al. 1994). Building on the information learned from previous studies (Bulak 1997; Maluk and Abrahamsen 1999), this survey added 34 species of fish to the existing list of species confirmed as present in the park. While an effort was made to maximize our opportunity to collect all the fish species present in the park, it is likely that some species were not collected. The new information revealed through this study however, will provide the park staff with the baseline inventory information required to make sound management decisions.

Drought conditions prevailed during this study, affecting the fish community and our sampling efficiency. During a drought, the landscape, habitat, and water quality change dramatically. The National Oceanic and Atmospheric Administration (2003) reported that “On a statewide basis, the Carolinas were the epicenter of the 2002 drought in the Southeast” (Figure 7). These conditions evaporated many potential sampling sites within the CONG, confining the fish community to a reduced volume of water. The drought also allowed us to sample some areas much more effectively due to the lower water levels. Cedar Creek, for example, typically flows at a depth of about 1.2 to 1.5 meters of water. During flooding events the water often rises as high as 4.5 meters. Throughout the summers of 2001 and 2002, Cedar Creek was flowing at less than 0.5 meters deep for most of the sampling season. Quantitative backpack electrofishing is much more effective in wadeable streams where the depth is less than half a meter.

By sampling during a drought cycle we observed the fish community’s response to a substantial natural alteration in their habitat. The fish community of CONG is regularly exposed to fluctuating water levels as a result of flood and drought events. Thus, it was not surprising to find vigorous fish communities inhabiting areas where water volume and environmental quality is regularly affected by drought. The indicator species for group 1 communities (Eastern mudminnow, Redfin pickerel, Flier and Pirate perch) are all tolerant of harsh environmental conditions. In fact, during long periods of drought, the Eastern mudminnow can survive by burying itself in the mud. Thus it is not surprising that a component of the CONG community are those species that can tolerate harsh environmental conditions.

A model was developed that enabled us to predict the fish community structure under the diversity of habitat conditions observed during this study. Using the provided model, if a population differed from the predicted population, we would have grounds to suspect that an additional factor is acting on the stream that was not present at the time the model was developed. Clearly, this model assumes summertime drought conditions and that samples are confined to the CONG. If these assumptions are met, deviations from the expected community may imply that anthropogenic factors are influencing the community.

Three of the four sites that did not conform to model predictions were expected to be comprised of the TSD/LMB/RES community. The true group for the three sites was the FLR/EMM community. The habitat correlations from the NMS ordination tell us that the TSD/LMB/RES community is associated with different habitat conditions than the FLR/EMM community. The interpretation of this shift is that these three sites were comprised of communities that were uncharacteristic for the present habitat conditions.

The first of the four non-conforming sites was 103. This is the Tom's Creek site that clustered with the FLR/EMM community rather than with the SFS/DKS community that was characteristic of the other Tom's Creek samples. In this case, the morphology of the stream between the SFS/DKS community sites and site 103 was so different that we did not expect it to fall within the SFS/DKS community. However, it was expected to have a TSD/LMB/RES community. It is interesting that the fauna here was comprised of more tolerant species than expected and that this site is down-stream from McKenzie creek. McKenzie Creek is the location of the outlier site that formed Group 4 in the cluster analysis. This may be an indication of either anthropogenic effects or some other stressor not measured in this study.

The second and third misclassified sites (116 and 122) were sampled on August 15th and 16th, 2001 respectively. In the 5 days preceding the 15th of August, rain events caused the water levels in Cedar Creek to rise almost half a meter. Both of these sites were creeks or guts that fed the main channel of Cedar Creek. They were both smaller sites that had recently become filled with water from Cedar Creek. Both were observed with the tolerant FLR/EMM community however they were predicted to contain the TSD/LMB/RES community. Sampling in these locations may have reflected the communities of fish present before the rain-induced habitat change.

The fourth misclassified site was sample 131-23. This site was predicted to contain the FLR/EMM community but contained the TSD/LMB/RES community. A likely explanation is that the habitat had recently degraded and the fish community had not fully shifted to accommodate the new conditions. Unfortunately, no additional samples were collected here after this sampling date to verify if the community shift eventually took place. At other sites (e.g. site 133) multiple samples documented a predictable shift in community structure from TSD/LMB/RES to FLR/EMM as conditions worsened during the drought.

Site 113 on McKenzie Creek was identified in this study as a degraded creek. Compared to other streams in the park, this site had uncharacteristically low species numbers, low species diversity, and an increased abundance of tolerant species. This site was an outlier in both the cluster analysis and the NMS ordination. Also, the DA model predicted a fish community that was not observed. Additional assessment of this drainage is necessary.

The model was tested by backcasting the original data through the model. Strictly speaking, the model should be tested with new data. With further testing, verification and modification, the developed model can be expanded to predict community structure under normal meteorological summer conditions.

Conclusions:

By sampling a variety of habitats in Congaree National Park we were able to develop a comprehensive inventory of fish that inhabit the park under drought conditions. A total of 56 species of fish were observed within the park's boundary and at least 24 had not been documented previously.

Three distinctive fish communities were found in the streams of the CONG. These communities were correlated with the different habitat conditions present at different locations. Sites with relatively low flows and oxygen had fish that were the most tolerant to the adverse conditions found there. Drought was observed to be one of the dominant forces shaping the habitat and the communities of fish present in the park during the time period we sampled there.

A model was developed that predicted the expected fish communities based on habitat. This model can be applied to drought conditions in the CONG. Additional sampling is needed to expand the scope of the model. This approach allowed for a broad interpretation of the factors that alter fish communities in a CONG.

The drought conditions that prevailed for the duration of this project enabled us to sample locations that normally would be unavailable. While we were able to improve efficiency, a negative aspect of the drought was that the data set described the present communities under extreme conditions. Additional research is required to determine how the different communities of fish respond to other meteorological conditions.

McKenzie Creek was identified as a degraded creek. To determine the extent of the degradation, the effect the degradation may be having on Tom's Creek and the causes of the degradation, further assessment of its drainage is needed.

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Tables:

Table 1: Sampling measurements taken at all of the stream, lake and pond samples during the SCDNR fish survey of the Congaree National Park and surrounding areas, 1999 through 2002.

Sample Information	Physical Parameters	Chemical Parameters	Biological Parameters
Date (of sample)	Sample length [1]	Conductivity	Fish species **
Stream Name	Avg. width (5 measurements) [1]	Conductance	Length (mm) on all fish [2]
Number of People Present	Avg. depth (15 measurements) [1]	Temperature	Fish count[2]
Cedar Creek gauge height [1*]	Flow (A categorical velocity measurement) [1, 4]	pH	Collected specimens
River basin	Discharge [1]	Dissolved O2	
Latitude	Area	% Dissolved O2	
Longitude	Volume [1]	Salinity	
Reach code	Water level		
Access (Categorical description of how difficult site was to access)	Substrate type		
Sampling method	Habitat (Visual estimation) [3]		
Equipment type	Condition (Visual estimation)		
All equipment settings (Volts, Frequency, Pulse Width)	Suitability (Visual estimation)		
Number of passes [1]			
Duration (of sampling)			
Method (Boat, Backpack)			

1 Measured only at stream survey sites.
2 In the lake and pond samples length and weight was recorded at Weston and Wise Lakes only
3 The EPA's Rapid Bioassessment Visual Estimation Technique was used to determine the condition of the stream habitat (Barbour 1999).
4 Flow was categorized as either none, low, medium or high based on a visual estimation of relative flow rates in the swamp.
* Gauge height only recorded for some locations. Historic water levels are available through USGS.
** Pass number is indexed to every fish in the stream samples to enable us to verify depletion sampling

Table 2: A complete list of all species and the total number of each species collected during the SCDNR fish survey of the Congaree National Park and surrounding areas, 1999 through 2002.

SCDNR Code	Family Name	Scientific Name	Common Name	National Park Sites		All Sites (Includes off-site samples)
				Streams	Lakes	
LNG	Lepisosteidae	*Lepisosteus osseus*	Longnose gar	12	P	16
BFN	Amiidae	*Amia calva*	Bowfin	1	P	7
AEL	Anguillidae	*Anguilla rostrata*	American eel	1		2
GZS	Clupeidae	*Dorosoma cepedianum*	Gizzard shad	5		5
TFS		*Dorosoma petenense*	Threadfin shad	4		4
EMM	Umbridae	*Umbra pygmaea*	Eastern mudminnow	195	P	207
RFP	Esocidae	*Esox americanus*	Redfin pickerel	539	P	568
CHP		*Esox niger*	Chain pickerel	24	P	27
GFS	Cyprinidae	*Cyprinella chloristius*	Greenfin shiner	1	P	1
WFS		*Cyprinella nivea*	Whitefin shiner	60		80
CRP		*Cyprinus carpio*	Common Carp		P	1
ESM		*Hybognathus regius*	Eastern silvery minnow	362		362
BHC		*Nocomis leptocephalus*	Bluehead chub	4		7
GLS		*Notemigonus crysoleucas*	Golden shiner	87		100
DKS		*Notropis cummingsae*	Dusky shiner	365		609
STS		*Notropis hudsonius*	Spottail shiner	19		19
YFS		*Notropis lutipinnis*	Yellowfin shiner*			1
TLS		*Notropis maculatus*	Taillight shiner	11	P	27
CSH		*Notropis petersoni*	Coastal shiner	39		48
SFS		*Pteronotropis hypselopterus*	Sailfin shiner	161		563
CCS	Catostomidae	*Erimyzon oblongus*	Creek chubsucker	266	P	316
SPS		*Minytrema melanops*	Spotted sucker	7	P	28
SHR		*Moxostoma macrolepidotum*	Shorthead redhorse	7		7
SBH	Ictaluridae	*Ameiurus brunneus*	Snail bullhead	4		4
YBH		*Ameiurus natalis*	Yellow bullhead	70		95
BBH		*Ameiurus nebulosus*	Brown bullhead	5		5
FBH		*Ameiurus platycephalus*	Flat bullhead	9		9
CCF		*Ictalurus punctatus*	Channel catfish	7		7
TPM		*Noturus gyrinus*	Tadpole madtom	116		119
MGM		*Noturus insignis*	Margined madtom	156		184
FCF		*Pylodictis olivaris*	Flathead catfish	1		1
SWF	Amblyopsidae	*Chologaster cornuta*	Swampfish	3		5
PIP	Aphredoderidae	*Aphredoderus sayanus*	Pirate perch	1020	P	1074
LTM	Cyprinodontidae	*Fundulus lineolatus*	Lined topminnow	5		6
MSQ	Poeciliidae	*Gambusia holbrooki*	Mosquitofish	1111	P	1150
BSS	Atherinidae	*Labidesthes sicculus*	Brook silverside	71	P	116
WTP	Percichthyidae	*Morone americana*	White perch	6		6
MDS	Centrarchidae	*Acantharchus pomotis*	Mud sunfish	2		5
FLR		*Centrarchus macropterus*	Flier	335	P	356
BPS		*Elassoma zonatum*	Banded pygmy sunfish	84	P	91
BBS		*Enneacanthus chaetodon*	Blackbanded sunfish	1		3
BLS		*Enneacanthus gloriosus*	Bluespotted sunfish	17	P	39
BDS		*Enneacanthus obesus*	Banded sunfish*			1
RBS		*Lepomis auritus*	Redbreast sunfish	792	P	874
GSF		*Lepomis cyanellus*	Green sunfish	1		2
PPS		*Lepomis gibbosus*	Pumpkinseed	23	P	25
WAR		*Lepomis gulosus*	Warmouth	234	P	312
BLG		*Lepomis macrochirus*	Bluegill	624	P	771
DSF		*Lepomis marginatus*	Dollar sunfish	392	P	474
RES		*Lepomis microlophus*	Redear sunfish	182	P	198
SOS		*Lepomis punctatus*	Spotted sunfish	172	P	217
LMB		*Micropterus salmoides*	Largemouth bass	105	P	142
BLC		*Pomoxis nigromaculatus*	Black crappie	1	P	3
SWD	Percidae	*Etheostoma fusiforme*	Swamp darter	1		1
TSD		*Etheostoma olmstedi*	Tessellated darter	222		232
SCD		*Etheostoma serriferum*	Sawcheek darter	84	P	95
SGD		*Etheostoma thalassinum*	Seagreen darter*			11
YLP		*Perca flavescens*	Yellow perch	100	P	168
PDD		*Percina crassa*	Piedmont darter	7		7
			Total Fish:	8133	n/a	9813
			Total Species:	55	27	59

* Fish found during the project but not within Congaree National Park.

P = Present

Table 3: Pearson and Kendall habitat correlations with non-metric multidimensional scaling ordination axes calculated from data collected during the SCDNR fish survey of the Congaree National Park and surrounding areas, 1999 through 2002. Asterisk indicates significant correlations.

Axis	1			2		
	r	r^2	tau	r	r^2	tau
Temperature	0.176	0.031	0.224	0.227	0.052	0.105
Canopy	-0.364	0.132	-0.263	-0.023	0.001	0.074
Condition	0.732	0.536*	0.529	-0.484	0.234	-0.221
DO	0.729	0.531*	0.501	-0.336	0.113	-0.188
pH	0.012	0.00	0.077	0.341	0.116	0.302
Specific Conductance	-0.569	0.324*	-0.525	0.501	0.251*	0.305
Width	0.320	0.102	0.235	0.140	0.02	0.197
Depth	0.393	0.154	0.299	-0.033	0.001	-0.002
Flow	0.610	0.372*	0.487	-0.279	0.078	-0.231
Volume	0.345	0.119	0.290	0.090	0.008	0.129

Table 4: The relationship of fish community type in Congaree National Park 1999 through 2002 to three environmental variables as determined through non-metric multidimensional scaling (Clarke 1993).

Community Type	Specific Conductivity	DO	Flow
Community Group 1	↑	↓	↓
Community Group 2	↑	↑	↑
Community Group 3	↓	↑	↑

↑ = group is correlated with high values (e.g. Group 1 inhabits water with high specific conductivity)
↓ = group is correlated with low values (e.g. Group 1 inhabits water with low DO and flow)

Table 5: Percentage of fish from each tolerance guild (NCDENER 2001) in each group collected during the SCDNR fish survey of the Congaree National Park and surrounding areas, 1999 through 2002. Each group has been coded to match the icons used in the cluster analysis and NMS ordination.

		Intolerant	Moderate	Tolerant
Community Group 1	■	1.47	69.97	28.55
Community Group 2	▲	1.04	75.71	23.25
Community Group 3	∆	0.90	87.27	11.84

Figures:

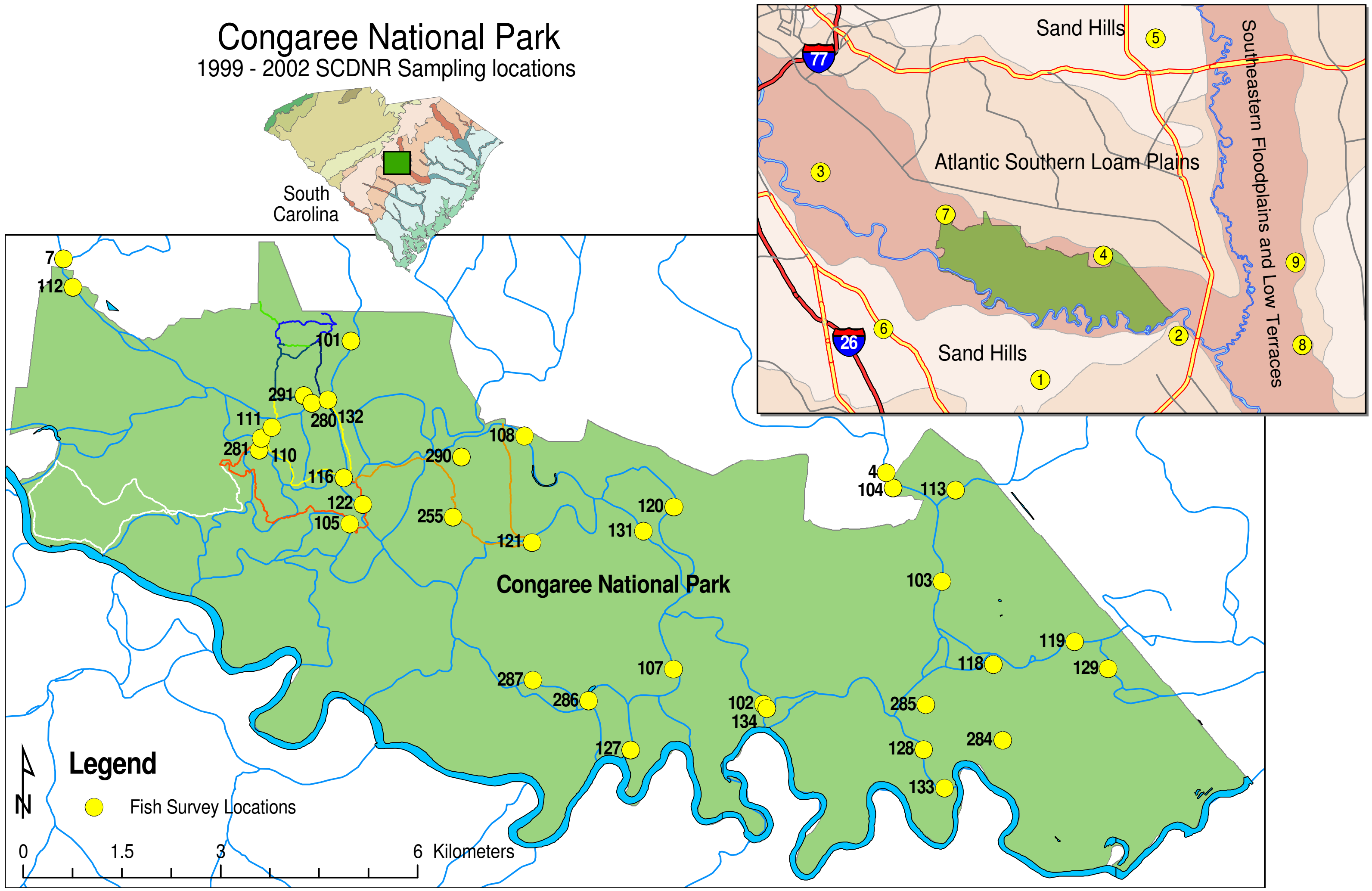

Figure 1: Congaree National Park 1999 through 2002 fish sampling locations.

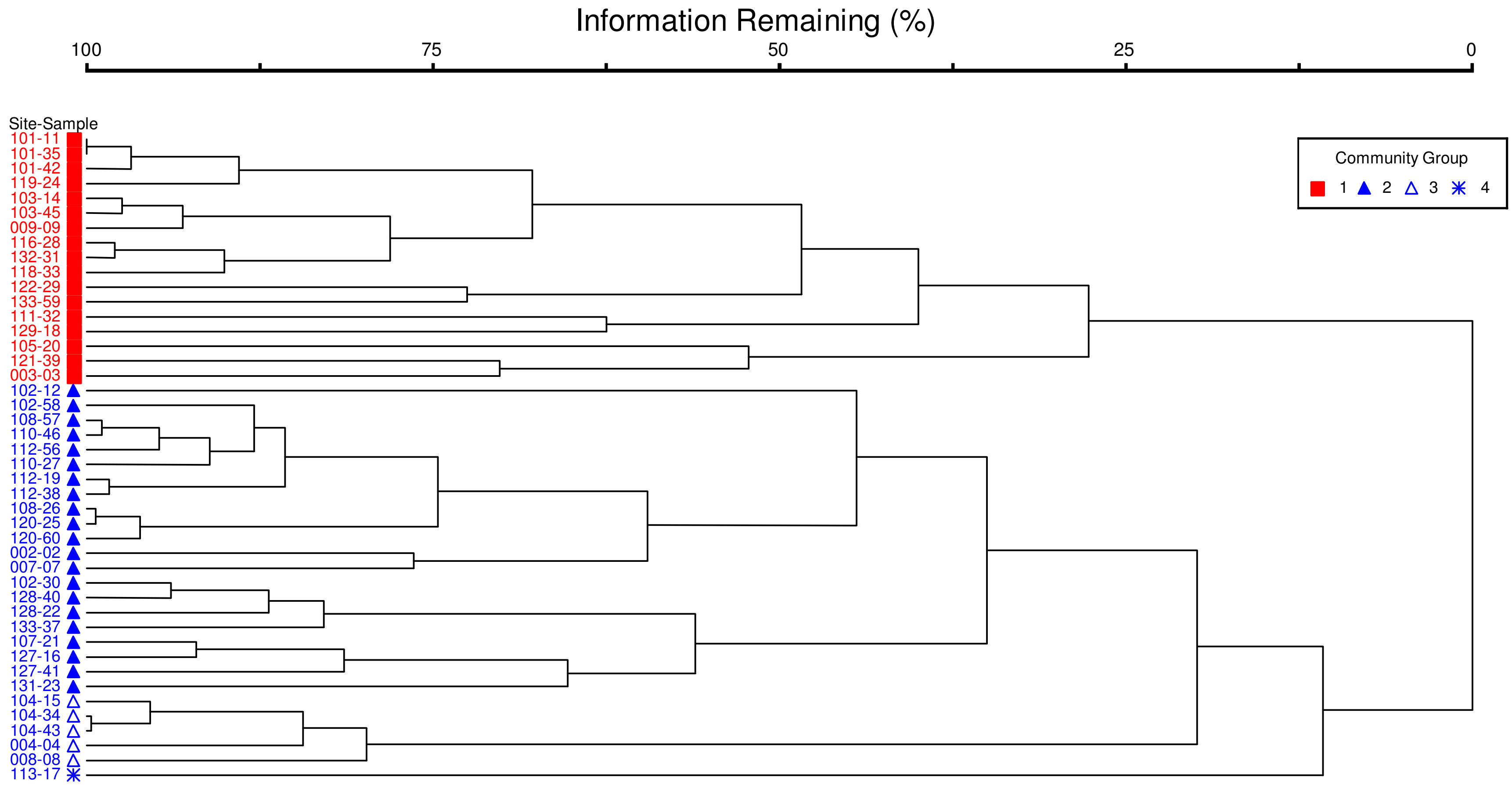

Figure 2: Similarity of stream fish communities within and near Congaree National Park as indicated by cluster analysis (Sorensen (Bray-Curtis, Flexible Beta = -0.15)). Rare species were removed from the dataset before analysis. Groups were classified as distinct if an adjacent cluster retained less than 25% of its information.

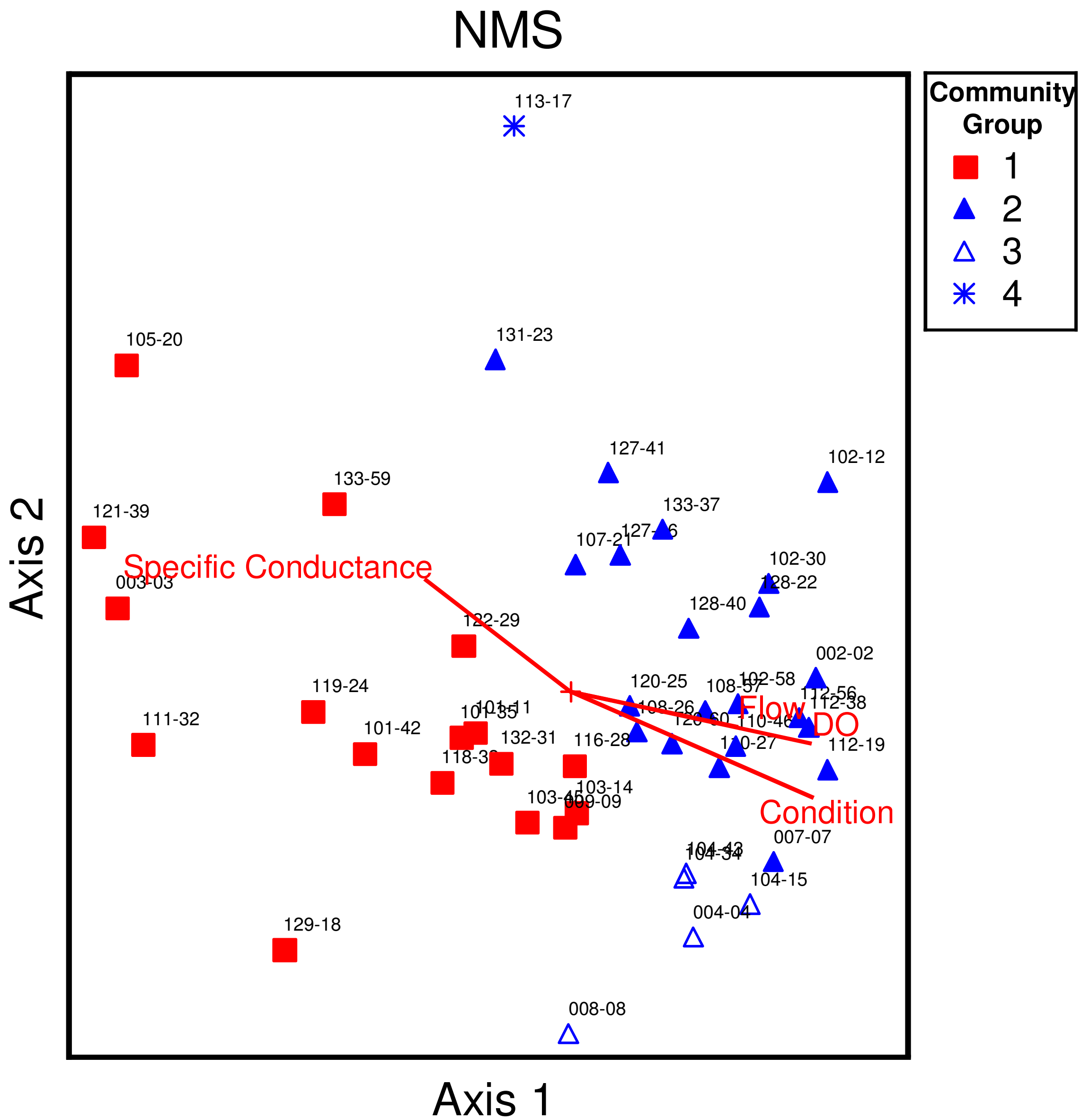

Figure 3: An NMS ordination of fish communities at sampling locations in Congaree National Park. Sites closer together have more similar fish communities. The groups were assigned based on the results of a cluster analysis. To facilitate interpretation of the axes, the habitat variables that were most strongly correlated with the two axes have been overlaid as vector lines.

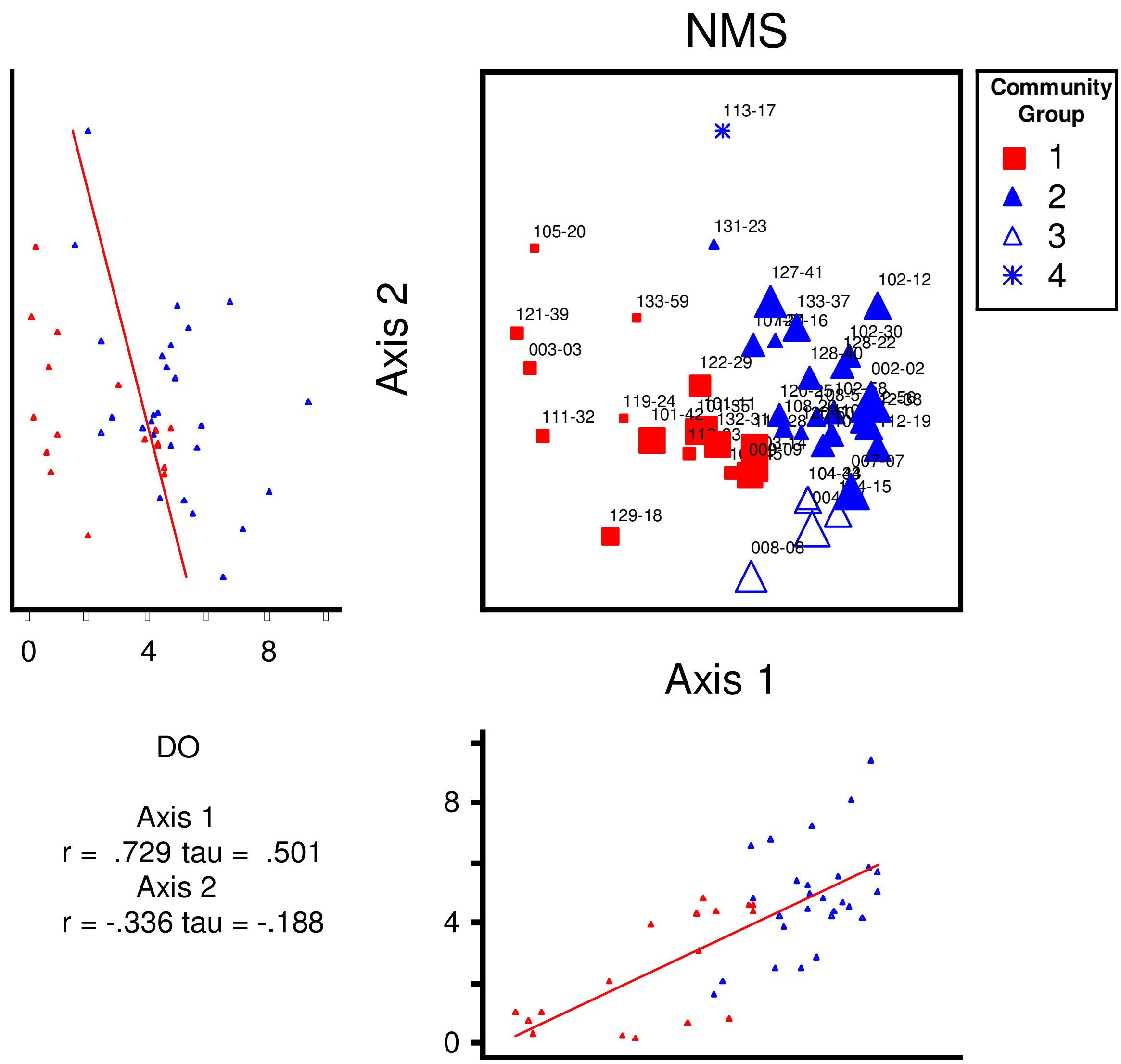

Figure 4: The NMS ordination of fish communities at sampling locations in Congaree National Park and the correlation of the two axes with dissolved oxygen (DO). The size of the points in the NMS ordination have been scaled to better illustrate the locations where higher DO was recorded. Sites with higher DO have larger points than those with lower DO. Axis 1 shows a positive correlation with DO.

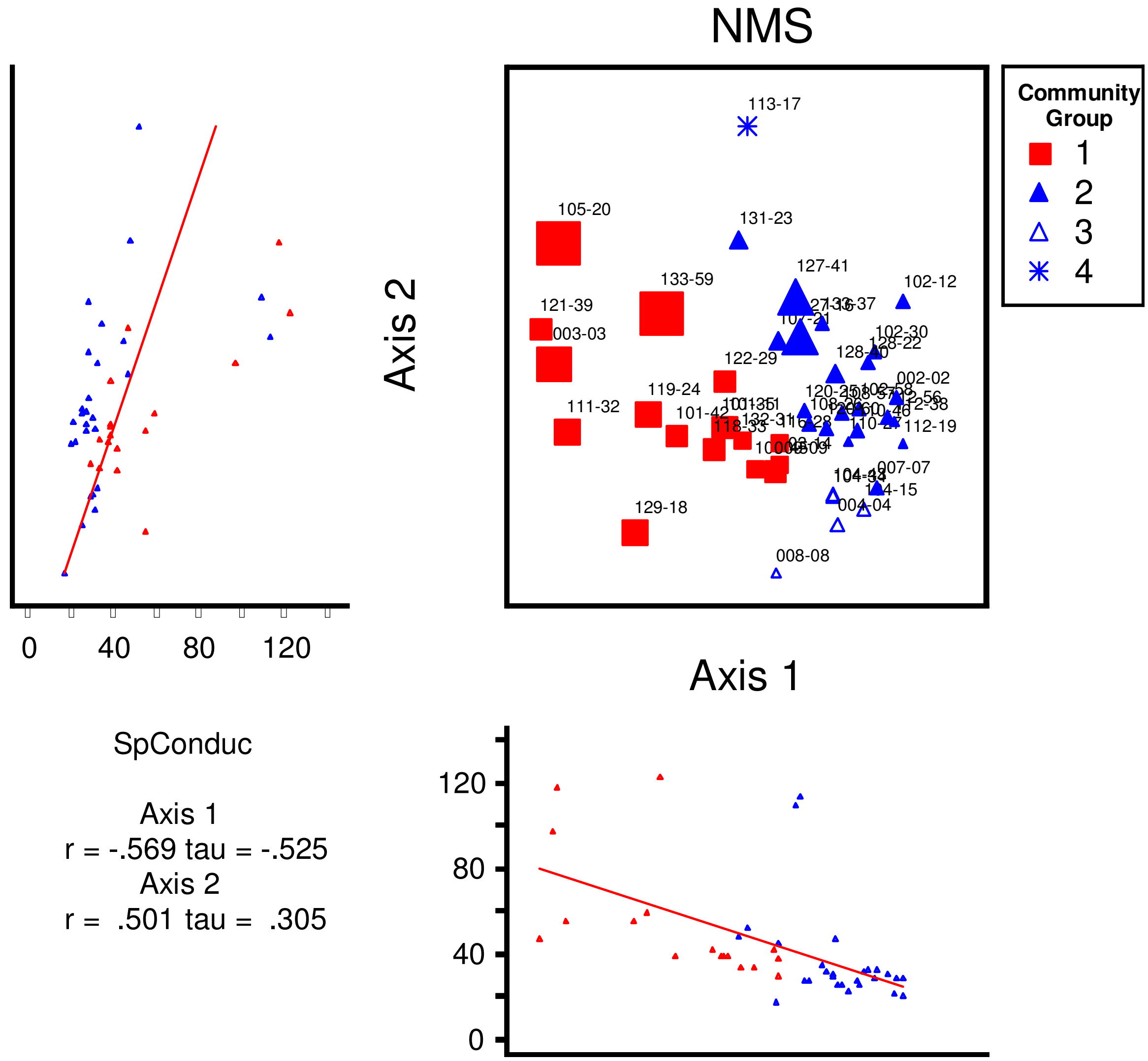

Figure 5: The NMS ordination of fish communities at sampling locations in Congaree National Park and the correlation of the two axes with specific conductivity. The sizes of the points in the NMS ordination have been scaled to better illustrate the locations where higher specific conductance was recorded. Sites with higher conductance have larger points than those with lower specific conductance. Axis shows a negative correlation with conductance.

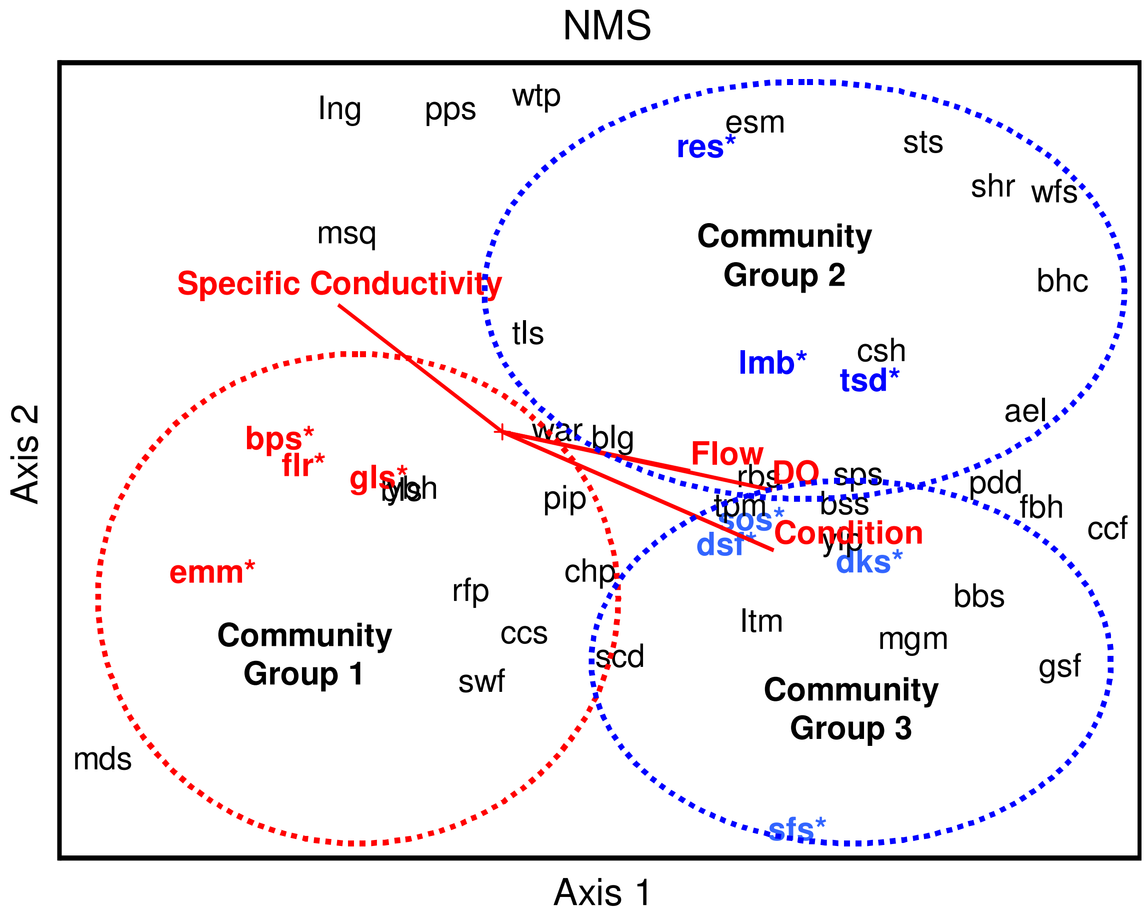

Figure 6: A plot of fish species on the NMS ordination axes. To facilitate interpretation of the axes, the habitat variables that were most strongly correlated with the two axes have been overlaid as vector lines and approximate boundaries have been drawn around each community. Species marked with an asterisk and bold are indicator species. Species codes can be found in (Table 2).

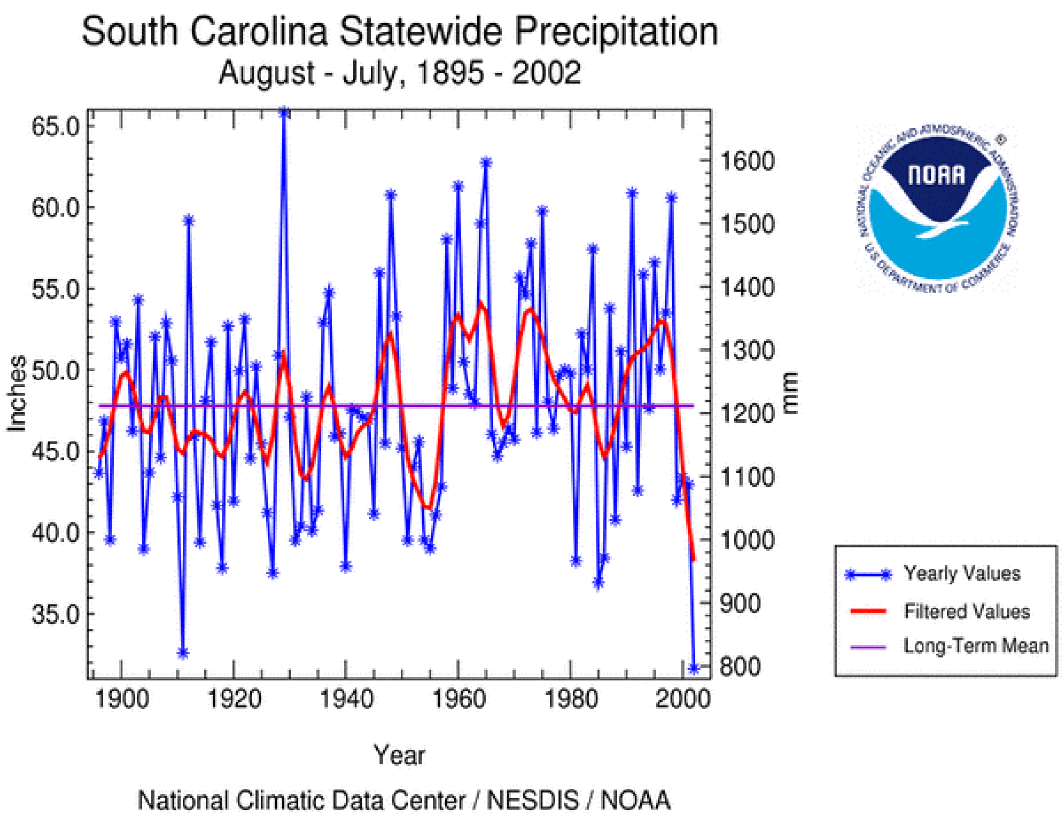

Figure 7: South Carolina statewide precipitation; August – July, 1895 through 2002. Note the very low values for the period from 1999 through 2002. 2002 had the driest year on record for SC.

Appendix:

Appendix 1: A complete list of sample dates and locations for the Congaree National Park SCDNR fish survey and inventory, 1999 through 2002. Valid sites were those that were sampled using the pass-depletion quantitative sampling method and intended for inclusion in the community analysis (e.g. only stream sites). Sites that were not valid for the community analysis were used for inventory only.

Site ID	Date	Site Name	Latitude	Longitude	National Park	Valid	Type
001-01	10/4/2000	Bates Mill Creek	33.72295845	-80.77924355	No	No	Stream
002-02	10/13/00	Buckhead Creek	33.75423128	-80.66137041	No	Yes	Stream
003-03	10/20/00	Boggy Gut	33.87164496	-80.96715537	No	Yes	Stream
004-04	10/25/00	Tom's Creek	33.81174475	-80.72499673	No	Yes	Stream
005-05	10/27/00	Cates Creek	33.96691856	-80.68027441	No	No	Stream
006-06	11/1/2000	Big Beaver Creek	33.7595766	-80.9135421	No	No	Stream
007-07	11/3/2000	Myers Creek	33.84138453	-80.86017065	No	Yes	Stream
008-08	11/8/2000	Tavern Creek	33.74735955	-80.55547405	No	Yes	Stream
009-09	11/15/00	Shanks Creek	33.80627939	-80.56096211	No	Yes	Stream
010-10	1/15/2001	Weston Lake (upper)	33.82250978	-80.82070978	Yes	No	Pond
101-11	6/19/2001	Dry Branch	33.83003729	-80.81291696	Yes	Yes	Stream
102-12	6/26/2001	Cedar Creek	33.77995863	-80.74526442	Yes	Yes	Stream
134-13	6/26/2001	Cedar Creek	33.77938537	-80.74474199	Yes	No	Stream
103-14	6/27/2001	Tom's Creek	33.79677439	-80.71587493	Yes	Yes	Stream
104-15	6/28/2001	Tom's Creek	33.80966026	-80.72385918	Yes	Yes	Stream
127-16	7/10/2001	Dead River Gut	33.77375024	-80.76703804	Yes	Yes	Stream
113-17	7/11/2001	McKenzie Creek	33.80932684	-80.71356675	Yes	Yes	Stream
129-18	7/12/2001	Running Gut	33.78468187	-80.68857198	Yes	Yes	Stream
112-19	7/17/2001	Cedar Creek	33.8374576	-80.85862684	Yes	Yes	Stream
105-20	7/24/2001	Deep Jackson Gut	33.80488028	-80.81321866	Yes	Yes	Stream
107-21	7/25/2001	Horsepen Gut	33.7847961	-80.76005097	Yes	Yes	Stream
128-22	7/26/2001	Cedar Creek	33.77369525	-80.71895835	Yes	Yes	Stream
131-23	8/1/2001	Tupelo Gut	33.80376821	-80.76487727	Yes	Yes	Stream
119-24	8/2/2001	Running Lake Slough	33.78845714	-80.69405326	Yes	Yes	Stream
120-25	8/7/2001	Cedar Creek	33.8070864	-80.75991112	Yes	Yes	Stream
108-26	8/8/2001	Cedar Creek	33.81689699	-80.78441503	Yes	Yes	Stream
110-27	8/9/2001	Cedar Creek	33.8166869	-80.8277193	Yes	Yes	Stream
116-28	8/15/2001	Weston Lake Slough	33.81120299	-80.81418512	Yes	Yes	Stream
122-29	8/16/2001	Running Gut	33.80757225	-80.81104586	Yes	Yes	Stream
102-30	8/20/2001	Cedar Creek	33.77995863	-80.74526442	Yes	Yes	Stream
132-31	8/22/2001	Dry Branch	33.8219445	-80.81674919	Yes	Yes	Stream
111-32	8/24/2001	Weston Gut	33.81814891	-80.82596074	Yes	Yes	Stream
118-33	8/29/2001	Running Lake	33.78532206	-80.70747282	Yes	Yes	Stream
104-34	8/31/2001	Tom's Creek	33.80966026	-80.72385918	Yes	Yes	Stream
101-35	9/5/2001	Dry Branch	33.83003729	-80.81291696	Yes	Yes	Stream
116-36	9/7/2001	Weston Lake Slough	33.81120299	-80.81418512	Yes	No	Stream
133-37	9/12/2001	Cedar Creek	33.76835624	-80.71555466	Yes	Yes	Stream
112-38	9/14/2001	Cedar Creek	33.8374576	-80.85862684	Yes	Yes	Stream
121-39	9/19/2001	Moccasin Pond	33.80227225	-80.78317468	Yes	Yes	Stream
128-40	5/3/2002	Cedar Creek	33.77369525	-80.71895835	Yes	Yes	Stream
127-41	5/10/2002	Dead River Gut	33.77375024	-80.76703804	Yes	Yes	Stream
101-42	6/13/2002	Dry Branch	33.83003729	-80.81291696	Yes	Yes	Stream
010-44	6/18/2002	Weston Lake (upper)	33.82250978	-80.82070978	Yes	No	Pond

Site ID	Date	Site Name	Latitude	Longitude	National Park	Valid	Type
104-43	6/21/2002	Tom's Creek	33.80966026	-80.72385918	Yes	Yes	Stream
103-45	6/25/2002	Tom's Creek	33.79677439	-80.71587493	Yes	Yes	Stream
110-46	6/28/2002	Cedar Creek	33.8166869	-80.8277193	Yes	Yes	Stream
255-48	7/1/2002	Hall Lake	33.80575388	-80.7961997	Yes	No	Pond
290-47	7/1/2002	Lost Lake	33.81406296	-80.79480442	Yes	No	Pond
284-49	7/9/2002	Sam's Lake	33.7749407	-80.70597018	Yes	No	Pond
285-50	7/9/2002	Joe's Lake	33.77984852	-80.71854444	Yes	No	Pond
286-52	7/10/2002	Old Dead River Lake	33.78053262	-80.77393531	Yes	No	Pond
287-53	7/10/2002	Running Lake	33.78331841	-80.78308903	Yes	No	Pond
281-54	7/16/2002	Wise Lake	33.81506515	-80.82805319	Yes	No	Lake
280-55	7/17/2002	Weston Lake	33.82146652	-80.8193748	Yes	No	Lake
112-56	7/23/2002	Cedar Creek	33.8374576	-80.85862684	Yes	Yes	Stream
108-57	8/6/2002	Cedar Creek	33.81689699	-80.78441503	Yes	Yes	Stream
102-58	8/13/2002	Cedar Creek	33.77995863	-80.74526442	Yes	Yes	Stream
133-59	8/16/2002	Cedar Creek	33.76835624	-80.71555466	Yes	Yes	Stream
120-60	9/11/2002	Cedar Creek	33.8070864	-80.75991112	Yes	Yes	Stream

Note: Latitude and longitude measurements are in decimal degrees (WGS 84)