



Spring Communities Monitoring at Ozark National Scenic Riverways, Missouri

2007-2009 Status Report

Natural Resource Technical Report NPS/OZAR/NRTR—2011/511



ON THE COVER

Pulltite Spring, Ozark National Scenic Riverways, Missouri
Photo from the Heartland Inventory and Monitoring Network

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Executive Summary

The extensive karst topography in the area surrounding Ozark National Scenic Riverways (OZAR) contributed to the formation of more than 425 springs within the park. Springs at OZAR receive portions of their baseflows from deeper karst components as well as surficial groundwater traveling through a karst landscape. Contaminates from land and surface water are known to enter surficial groundwater through rapid recharge, facilitated by the soluble bedrock system of fissures and sinkholes. Pollutants can be conveyed over great distances to springs through relatively unimpeded interbasin and subsurface transport. Land use practices, particularly land clearing and associated increases in sediment and nutrient loads and other point and nonpoint discharges, present the greatest long-term threat to springs in the Ozark Highlands. Little information exists on the physical and biological impacts of contaminated groundwater within springs or within surface water fed by springs. The Heartland Inventory and Monitoring Network began a spring monitoring program in 2007 to provide a baseline for assessing impacts of anthropogenic and natural disturbances on the ecological integrity of springs at OZAR. This report summarizes monitoring data on aquatic vegetation, aquatic invertebrates, fish, habitat, and water quality collected from six large springs at OZAR from 2007-2009. All water quality parameters monitored indicate that conditions among the respective springs are good. The findings show the broad natural habitat diversity and the physical and chemical stability in these springs.

A broad diversity of aquatic vegetation occurs in the springs. Plant community structure in the springs has changed little since Steyermark studied them in the 1940s, although some species were not observed while others were documented for the first time.

The invertebrate fauna occurring in all of the springs was dominated by environmentally sensitive taxa. The dominance of intolerant taxa, and mainly representatives of the caddisfly genus, *Lepidostoma*, occurring in the springs indicates their respective water quality conditions are good.

Fish communities consisted largely of species sensitive to poor water quality conditions and siltation. Knobfin sculpin (*Cottus hypselurus*) and banded sculpin (*Cottus carolinae*) were the dominant species in most springs, with the exception of Round Spring, which consisted largely of bleeding shiners. Sculpins and bleeding shiner, require clean gravel and cobble substrates and high dissolved oxygen levels.

The preliminary findings presented here reflect the broad natural habitat diversity, and physical and chemical stability in these springs. Geographic location of the springs does not appear to be a primary contributing factor in the composition of their respective vegetation, invertebrate, or fish communities. The three years of data presented here suggest that physical habitat factors including flow, substrate size and diversity, and distribution and diversity of aquatic vegetation may play a primary role in structuring these communities. However, collecting and analyzing additional monitoring data are required to determine the importance of these factors and elucidate other unknown parameters that may be important for spring communities.

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Introduction

Ozark National Scenic Riverways (OZAR) was established to conserve and interpret unique scenic and other natural values and objects of historic interest, including the preservation of the Current River and the Jacks Fork River as free-flowing streams, preservation of springs and caves, management of wildlife, and provision for use and enjoyment of the outdoor recreation resources. The extensive karst topography in the area surrounding OZAR is conducive to the formation of springs (Mugel et al., 2009). Within the karst terrain of OZAR there are more than 425 springs. Although most of these springs are relatively small, six are defined as 1st and 2nd magnitude, having discharges of at least 2.8 m³/second and 0.28 to 2.8 m³/second, respectively (Meinzer, 1927). The largest (Big Spring) has a maximum recorded discharge greater than 36 m³/sec and is ranked as one of the five largest springs in North America (Brune 1981).

Springs at OZAR receive portions of their baseflows from deeper karst components as well as surficial groundwater traveling through a karst landscape. Contaminates from land and surface water are known to enter surficial groundwater through rapid recharge, facilitated by the soluble bedrock system of fissures and sinkholes. Pollutants can be conveyed over great distances to springs through relatively unimpeded interbasin and subsurface transport. Karst springs have limited self-purification capacity because of low retention and adsorption within vast and often undescribed recharge areas. These springs are highly vulnerable to biological and chemical degradation and may represent the ultimate challenge in water quality protection (Gibert, 1990; Imes and Fredrick 2002). Despite the large amount of literature explaining groundwater contamination and its complexities, there is little information on the physical and biological impacts of contaminated groundwater within springs or within surface water fed by springs. (Williams, 1991; Notenboom *et al.*, 1994; van der Kamp, 1995). Land use, particularly vegetation clearing practices with associated increases in sediment and nutrient loads and other point and nonpoint inputs to surface water, have been reported as the largest long-term threat to streams and springs in the Ozark Highlands (Duchrow, 1977; Jacobson and Primm, 1997; Scott and Udouj, 1999; Imes and Frederick, 2002). Other impacts to spring integrity include disrupted stream channel geomorphology, increased sediment deposition and bank erosion, increased light penetration and water temperature, increased periphyton biomass resulting from nutrient loading, and decreased leaf litter and woody debris. Recent studies of the possible effects of global climate change indicate that increases in annual average water temperature (Hogg and Williams, 1996; Poff et al., 2002; Johnson, 2007) and changes in discharge (Erman and Erman, 1995) may impact spring communities as well.

Surveys of aquatic vegetation, fish, and invertebrate communities establish necessary inventories and aid in detection of ecosystem disturbances, such as water quality degradation or introduction of invasive, non-native species. Little monitoring has been conducted for spring systems in North America, including those at OZAR. Some water quality data for the springs included in this study have been collected by park resource management staff since 1983. Parameters collected include nutrients, microbiological, chlorophyll a, total alkalinity, temperature, dissolved oxygen, pH, specific conductance, turbidity, current velocity, and discharge. Data are stored on the U.S. EPA STORET Data Warehouse for the Current River watershed (<http://iaspub.epa.gov:huc=11010008>). These data are not analyzed in this report. The Heartland Inventory and Monitoring Network began a spring monitoring program in 2007 to provide a baseline for

assessing the impacts of anthropogenic and natural disturbances on the ecological integrity of springs at OZAR (Bowles et al. 2008).

The objectives of this study were to: 1) Determine the annual status and trends in species diversity, abundance, and community metrics for vegetation, invertebrates, and fish occurring in the large springs at OZAR, and 2) Relate the community data to overall water quality and habitat condition (DeBacker *et al.*, 2005). This report summarizes the monitoring data collected from 2007-2009.

Methods

Reach Selection

Methods and procedures used in this report follow Bowles *et al.* (2008). Sampling was conducted annually at each of six 1st or 2nd magnitude springs (Table 1) located at Ozark National Scenic Riverways, Missouri (Fig. 1), during late July-early August of 2007-2009. These springs were studied because they are the largest in the park and of greatest concern to park management. Data on aquatic vegetation, invertebrates, water quality, and in-stream habitat were collected at each spring annually. Fish communities and fish-related habitat parameters (fish cover and bank/riparian cover) were placed on a rotational schedule, in which two springs were sampled each year: Alley and Welch springs in 2007, Blue and Round springs in 2008, and Big and Pulltite springs in 2009.

At each spring, a sampling reach was established that satisfied specific requirements necessary to obtain representative and unbiased samples for all abiotic and biotic parameters being monitored. The portion of the spring run to be sampled was unique for each spring because of the unique sizes and other physical characteristics. We applied a weighting factor that accounted for variation among average widths (Table 2) to ensure a uniform sampling effort that represented each spring's total area. Reach length was based on a weighting factor that used average wetted width and the minimum reach length established by National Water-Quality Assessment Program (Moulton *et al.*, 2002; Bowles *et al.*, 2008). The designated sampling reach lengths allowed for inclusion of representative macrohabitats (riffle, run, and pool habitats) present. Runs were the most common habitats among all habitat types within the springs.

The sampling reach of each spring began as close to the spring source as practical, taking into consideration depth, flow, and crew safety near the spring source. The sampling reach was divided into 11 equally spaced transects beginning at the most upstream point and proceeding downstream (Fig. 2). The only exception to this was Welch Spring, where only three transects were used because the entire spring run is only 36 m long before its confluence with the Current River. Transects defined the sample locations with odd numbered transects used for aquatic vegetation samples, even numbered transects used for invertebrate sample locations, and physical habitat collected along each transect. Fish were sampled from the entire length of the reach by electrofishing. A calibrated datalogger (YSI 6600 or YSI 6920) was deployed immediately upstream of the first transect for a minimum of 48 hours.

Table 1. OZAR springs chosen for long-term monitoring.

Spring name	Spring magnitude and type (Meinzer 1927)	County	Quad Map	GPS coordinates	Rate of Flow (m³/sec) (Vineyard et al. 1974)
Alley Spring	1st , conduit	Shannon	Alley Spring	N37° 9.247' W91° 26.499'	1.51 – 29.68
Big	1st , conduit	Carter	Big Spring	N36° 57.137' W90° 59.646'	6.61 – 36.40 (est.)
Blue	1st , conduit	Shannon	Powder Mill	N37° 9.956' W91° 9.789'	1.74 – 6.61
Round	2nd, conduit	Shannon	Round Spring	N37° 16.953' W91° 24.458'	0.28 – 14.56
Pulltite	2nd, conduit	Shannon	Round Spring	N37° 20.103' W91° 29.408'	0.16 – 3.98
Welch	1st , conduit	Shannon	Cedar Grove	N37° 23.631' W91° 34.459'	1.96 – 9.27

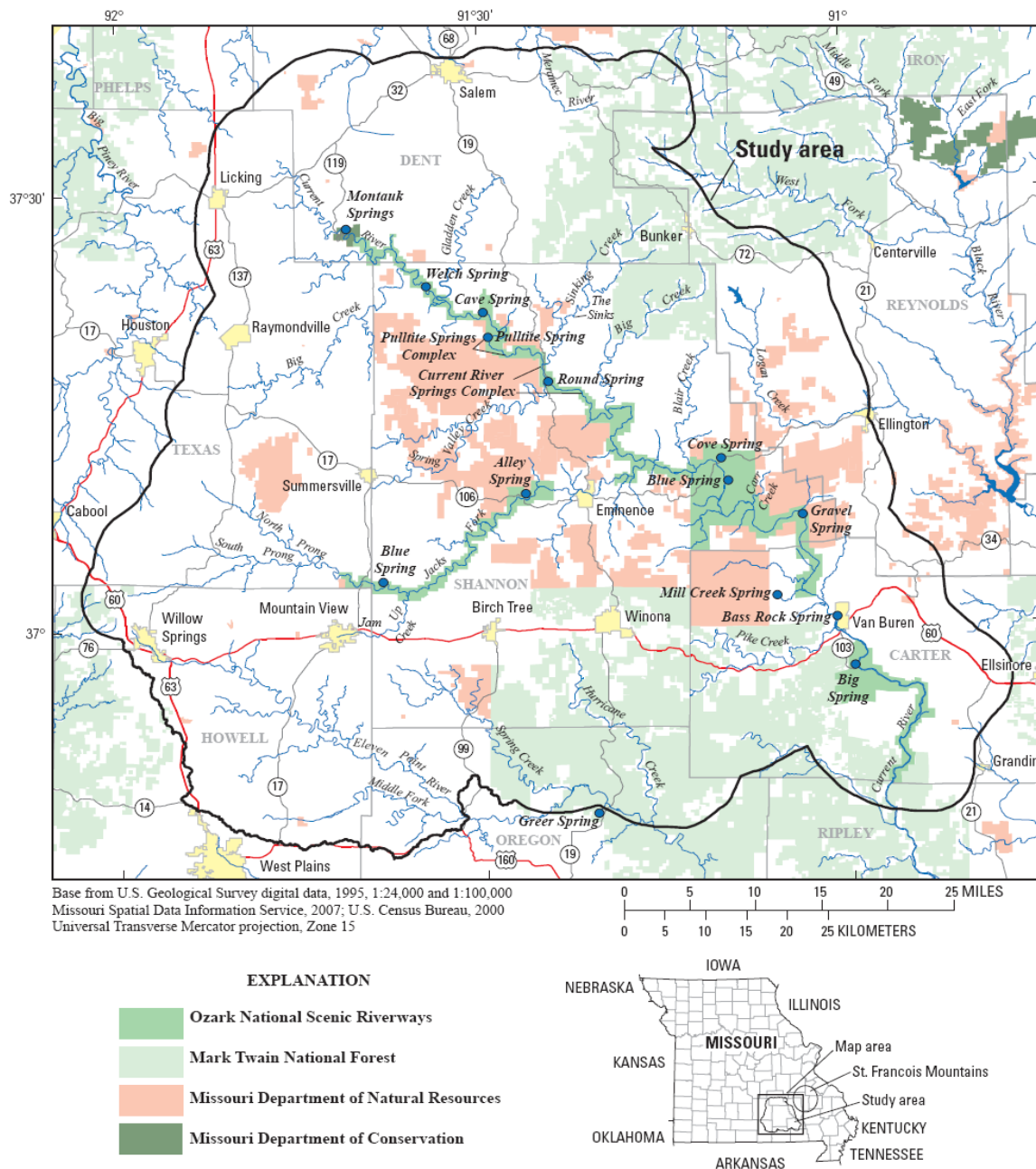


Figure 1. Map showing the general locations of large springs at Ozark National Scenic Riverways, Missouri. From Mugal et al. (2009). Springs sampled in this study are shown in Table 2. The black line demarcates the study area used by Mugal et al. (2009).

Table 2. Weighting factors and length of sampling reaches for large springs at OZAR.

Spring	Total Length (meters)	Average Width (meters)	Weight Factor (WF)	150 m X WF	Transect Interval (m)
Alley	800	19	$19/15 \approx 1.3$	190 m	19
Big	600	46	$46/15 \approx 3.1$	460 m	46
Blue	250	16	$16/15 \approx 1.1$	160 m	16
Pulltite	250	15	$15/15 \approx 1.0$	150 m	15
Round	300	24	$24/15 \approx 1.6$	240 m	24
Welch	36	15	$15/15 \approx 1.0$	36 m	18

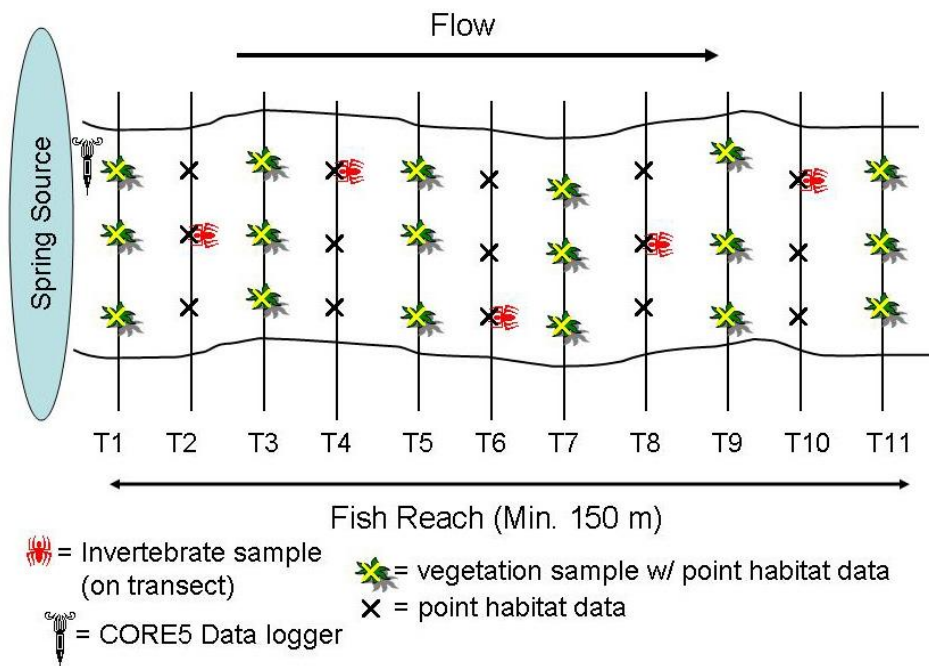


Figure 2. Transect location and layout within a spring run. The fish sampling reach at Welch Spring is only 36 meters.

Aquatic Vegetation

Aquatic vegetation was assessed in three equally-spaced 1 m² sample cells with a PVC sampling frame located on transects 1, 3, 5, 7, 9 and 11 delineating the cells and using a view bucket to observe the vegetation (Fig. 2). Plant species foliar cover in each sample cell was recorded using a modified Daubenmire scale (Daubenmire 1959, Table 3). Data were analyzed using the midpoints of the respective cover classes. Diversity metrics calculated for the vegetation data include Shannon's diversity index, Simpson's diversity index, species richness, species evenness, individual species frequency, percent foliar cover, species relative cover, species relative frequency, species importance value, % exotic species richness, and percent foliar cover exotic species. These metrics and their interpretation were described by Bowles, *et al.* (2008). Diversity data for vegetation (Shannon's index and Simpson's index) were expressed as effective number of species. Effective number of species for each diversity measure reflects the number of species found in a similar community when all species occur in equal density (Bowles et al. 2008). If all species occurred in equal abundance in the community within and among sample years then species richness, Shannon's index and Simpson's index would all be equal (Washington 1984).

Table 3. Scale used for assessing foliar cover of aquatic vegetation.

Daubenmire Cover Value Scale	
Cover Class Codes	Range of Cover (%)
7	95-100
6	75-95
5	50-75
4	25-50
3	5-25
2	1-5
1	0-0.99

Aquatic Invertebrates

For each spring, a single benthic sample was collected at transects 10, 8, 6, 4, and 2, using a Slack-Surber sampler (500 µm mesh) with a 0.25 m² sample frame (Fig. 2). Sample locations on transects alternated from left, middle, and right channel and starting location was rotated each year. This insured minimum, long-term disturbance to the spring run channel substrate. Samples were preserved in the field using isopropyl or ethyl alcohol containing approximately 10% buffered formalin. Samples were sorted in the laboratory following a subsampling routine described in Bowles *et al.* (2008). Taxa were identified to the lowest practical taxonomic level (usually genus) and counted. Metrics calculated for invertebrate data included taxa richness, Ephemeroptera, Plecoptera and Trichoptera (EPT) richness, % intolerant taxa, % dominant taxa (top 3), Shannon's diversity index, Simpson's diversity index, and Hilsenhoff Biotic Index (HBI). Diversity data for invertebrates (Shannon's index and Simpson's index) were expressed as effective number of species (Bowles et al. 2008).

Fish

Fish were collected throughout the entire sampling reach of each spring using backpack, towed barge, or boat electrofishing techniques depending on size of the spring run. Details on types of gear used in each spring can be found in Bowles *et al.* (2008). Most fish were identified to species in the field, but smaller specimens were fixed in 10% buffered formalin, taken to the laboratory, and identified. For each reach, a subsample of 30 fish from each species were measured (lengths and weights) and anomalies recorded. The remaining specimens of each species were counted for abundance estimates. Metrics calculated for fish communities included species richness, Simpson's diversity index, and catch per unit effort (CPUE). Size structure and percent composition of each species and of taxonomic groups sensitive to disturbance were also calculated for each spring.

Water Quality

Water quality parameters (temperature, dissolved oxygen, specific conductance, pH, and turbidity) were recorded hourly for approximately 48 hours at the head of each spring reach using a pre- and post-calibrated datalogger (YSI 6600 or YSI 6920). At Welch Spring, water quality parameters were measured as three static (point) readings at the upper, middle, and lower portion of the spring run. Stream discharge was measured using the methods of Carter and Davidian (1969). In 2007, discharge at Big Spring was measured, but in 2008 and 2009, the discharge reading at Big Spring was taken from USGS registering (real-time) staff gage No. 07067500 at the approximate time of sampling.

The water quality and discharge data collected for this study are intended to describe the prevailing conditions that influence the structure of the biotic communities. These data represent only a small snap-shot of the broader range of possible conditions over longer periods and should be cautiously interpreted. As such, they may help explain variability between sampling periods, but they should not be used as an analytical tool in the strictest sense (Bowles *et al.* 2008).

Habitat

Habitat was collected in three main categories: in-stream, fish cover, and bank/riparian cover. In-stream habitat was collected at three equally-spaced sample cells along each transect ($n = 33$; Fig. 2) and included both quantitative and qualitative measures. Current velocity (meters/second) and depth (cm) were recorded in the middle of each sample cell. Qualitative habitat variables (percent embeddedness, periphyton, filamentous algae, aquatic vegetation, deposition, and organic material) were estimated within the plant sampling frame as percentage categories (Table 4). Dominant substrate size was visually estimated based on the examination of three randomly selected substrate pieces collected from within the sampling cell. The Wentworth scale (Wentworth 1922) was used for visually estimating substrate size. In-stream habitat data were recorded as percentage categories and analyzed as midpoints of each category.

Table 4. Scale used for assessing coverage of in-stream and fish cover habitat variables.

Habitat Cover Value Scale	
Cover Class Code	Range of Cover (%)
4	>75
3	40-75
2	10-40
1	<10
0	0

Fish cover and bank measurements (fish-related habitat) were visually estimated at all transects in those years in which fish community sampling was conducted. In-stream fish cover (boulders and artificial cover) at each sample cell (n=33) was estimated as percentage categories (Table 4). Fish cover related to the banks (woody debris, trees/roots, overhanging vegetation, undercut banks and bluffs within 5 m of wetted edge) were estimated on the left and right side of each spring run (n=22). The dominant bank cover was categorized as trees, shrubs/saplings, grasses/forbes, bare, or artificial (n=22) and percent of each bank cover category was calculated. If a mix of cover was present in equal proportions, then more than one category of bank cover was recorded. All habitat categories recorded at each transect and percent cover was summarized for the spring run. Bank stability was assessed by visually categorizing the angle, percent vegetation, and height using measurement ranges, and substrate of the bank using relative substrate size (Table 5). A bank stability score was calculated for the left and right banks at each transect and averaged for the entire spring run.

Table 5. Scale used for assessing coverage of bank habitat variables.

Bank Angle, Degrees	Vegetative Cover (%)	Height (m)	Dominant Substrate	Bank Cover Types
1 = 0 – 30	1 = >80	1 = 0-1	1 = Bedrock/Artificial	TR = Large trees (> 3 in. dbh)
2 = 31-60	2 = 50-80	2 = 1.1-2	2 = Boulder/Cobble	SH = Small trees and shrubs
3 = >60	3 = 20-49	3 = 2.1-3	5 = Silt	GR = Grass and Forbes
	4 = <20	4 = 3.1-4	8 = Sand	BA = Bare rock/sediment
		5 = >4	10 = Gravel/Sand	AR = Artificial

Analysis

For the purpose of this study, we were not interested in whether metrics changed, but rather in the magnitude of change, and their biological importance (Bowles *et al.* 2008). Because sample size was small (n=3 years for vegetation and invertebrates, n =1 for fish), statistical analyses were not conducted on all data. Spearman's correlation ($\mu=0.05$) was used to evaluate the

relationship of Sørensen's similarity values with linear distances (km) among the respective springs, and the relationship between substrate size and embeddedness among springs.

Results

Aquatic Vegetation

The aquatic plant communities of the springs are diverse and dynamic, and they share many species in common (Figs. 3-9). Individual sample cells typically contained four to six taxa, although Welch Spring generally had only two to three species represented (Fig. 3). Shannon's Index effective number (H_e) ranged from 1.34 to 3.76 among sampling years and springs. Most H_e values for Alley and Blue springs were approximately 3 while those for Big, Pulltite, Round and Welch springs were generally closer to 2. Simpson's index effective numbers (D_e) ranged from 1.25 to 3.86 among sampling years and springs. Similar to the values recorded for H_e , D_e values were highest for Alley and Blue springs compared to the other springs. The effective number of species derived from Shannon and Simpson index values were relatively low compared to taxa richness. This suggests the dominance of a few taxa because the effective number of species will approximate species richness when all taxa in a sample are equally abundant. Vegetation communities among springs had moderate evenness values that ranged from 0.34 to 0.74. The broad overlap of standard errors of the mean indicate that observed differences among sampling years would not be statistically significant.

There was marked similarity in aquatic vegetation community structure among springs (Table 6). Sørensen's similarity values among springs ranged from 50% to over 93%. Big and Pulltite springs shared the most species in common (93%) while Blue and Welch springs shared the fewest species in common (50%). In general, Welch Spring shared the fewest species in common with the other springs, which may be due to its short (36 m) spring run, smaller sample size, and high current velocities that limit vegetation growth in the mid-channel. However, because the Welch spring run is short, we were able to visually examine nearly the entire bottom, and, based on those observations, the low species richness estimates for that spring are accurate. The degree of similarity of plant communities in the springs was not correlated to linear distance (km) between individual springs (Fig. 4). This suggests that similarity is not driven by proximity of one spring to another but by as yet undetermined environmental and habitat factors that occur in the springs. Additional analyses using distance between the springs along the river corridors rather than linear distance may help further describe the similarity among them.

The dominant taxa at Alley Spring were water-cress (*Nasturtium officinale*) and mosses (Bryophyta), with several other groups being well represented (Fig. 5). Long beak buttercup (*Ranunculus longirostris*) was the dominant species at Big Spring, although water-cress was also well represented in the spring run (Fig. 6). At Blue, Pulltite and Welch springs mosses were the dominant aquatic vegetation (Figs. 7-8, 10). Moss dominated Blue Spring until the last three downstream transects, where additional species were represented. Two leaf water milfoil (*Myriophyllum heterophyllum*), Illinois pondweed (*Potamogeton illinoensis*) and American bur-reed (*Sparganium americanum*) were the most abundant species present at Round Spring, but several other species were commonly represented in sample cells (Fig. 9). Foliar coverage of the substrate was extensive in all of the springs, with bare substrate occupying 20% or less of sample cells on average. Star duckweed (*Lemna trisulca*) was found at all springs except Welch Spring. This species has a S2 state heritage ranking indicating it is imperiled because of rarity or because

of other factors, demonstrably making it very vulnerable to extinction throughout its range. A complete list of plant species recorded from transects in each spring is in Appendix A, and a complete list of all species occurring in the springs is presented in Bowles et al. (2008).

Very few non-native plant species occurred in the springs, accounting for relatively little of the foliar cover on transects (Fig. 11). The most commonly occurring non-native plant was water-cress, but other such species represented include annual bluegrass (*Poa annua*), peppermint (*Mentha piperita*), creeping bentgrass (*Agrostis stolonifera*), creeping jenny (*Lysimachia nummularia*) and bitter doc (*Rumex obtusifolius*). Although all of these species are considered terrestrial or wetland plants, they grow in the spring runs at OZAR where some specimens are completely covered by water.

Several species previously reported from some springs are now missing from those springs. These species include (and the springs from which they were formerly known): grassleaf mudplantain, *Heteranthera dubia* (Big, Blue); star duckweed, *Lemna trisulca* (Pulltite); horned pondweed, *Zannichellia palustris* (Big, Round, Welch; now only found at Blue where it is rare); Illinois pondweed (Alley, Big, and Welch); long beak buttercup (Alley, missing Welch in 2008 and 2009); and leafy pondweed, *Potamogeton foliosus* (Alley, Big, Pulltite, Round). These presence/absence records are based on transect data, thorough visual inspection of the areas between transects and areas of the spring runs located above and below the sample reaches. Numerous other species of plants occurred in the springs at OZAR, but they were not present in sample cells. Complete inventories for aquatic plants in the springs are not presented in this report.

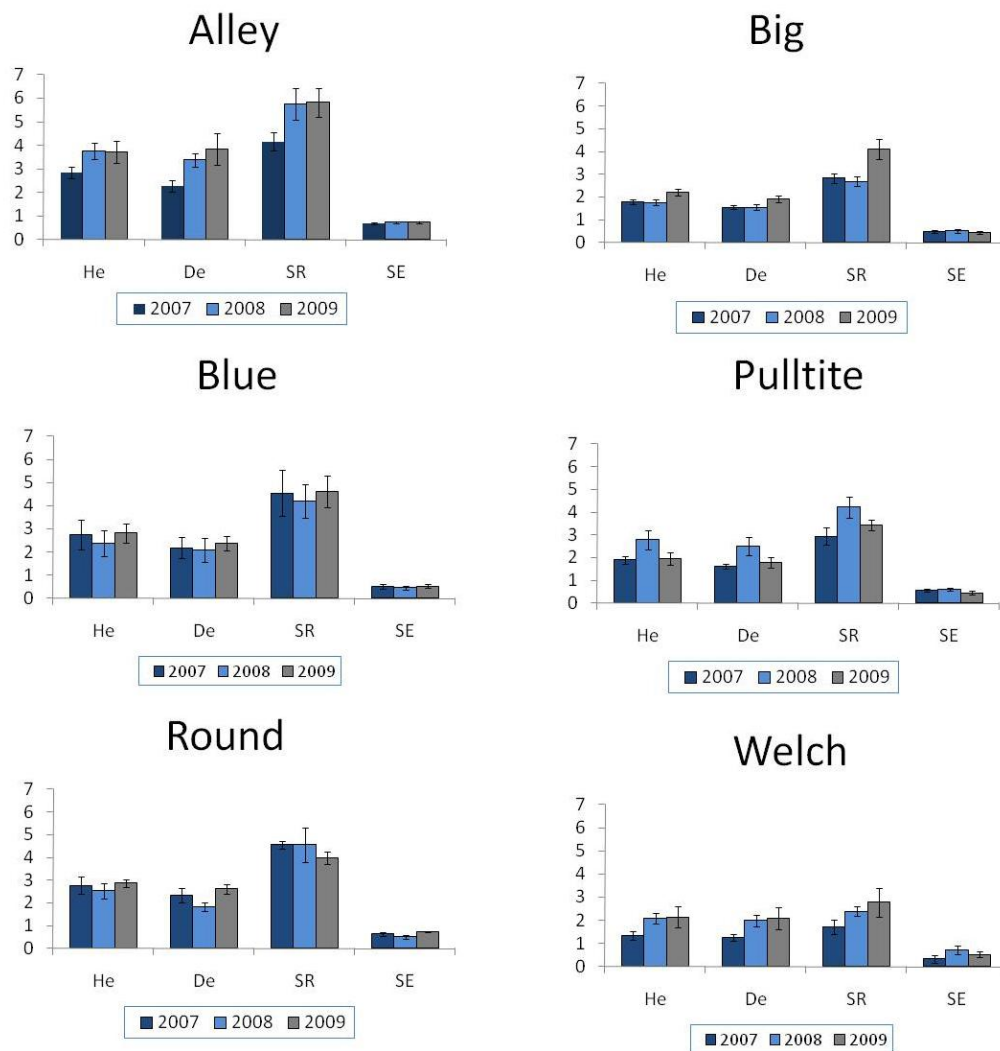


Figure 3. Metrics of effective number of species for aquatic vegetation collected at the six large springs at OZAR, 2007-2009. Error bars represent 1 standard error. He=Shannon's index effective number, De=Simpson's index effective number, SR=species richness, SE=Species evenness.

Table 6. Sørensen's percent similarity values for aquatic vegetation communities occurring in large springs at Ozark National Scenic Riverways, 2007-2009.

	Big	Blue	Pulltite	Round	Welch
Alley	80.00	74.29	80.00	75.00	60.87
Big		74.29	93.33	87.50	60.87
Blue			68.57	70.27	50.00
Pulltite				81.25	60.87
Round					64.00

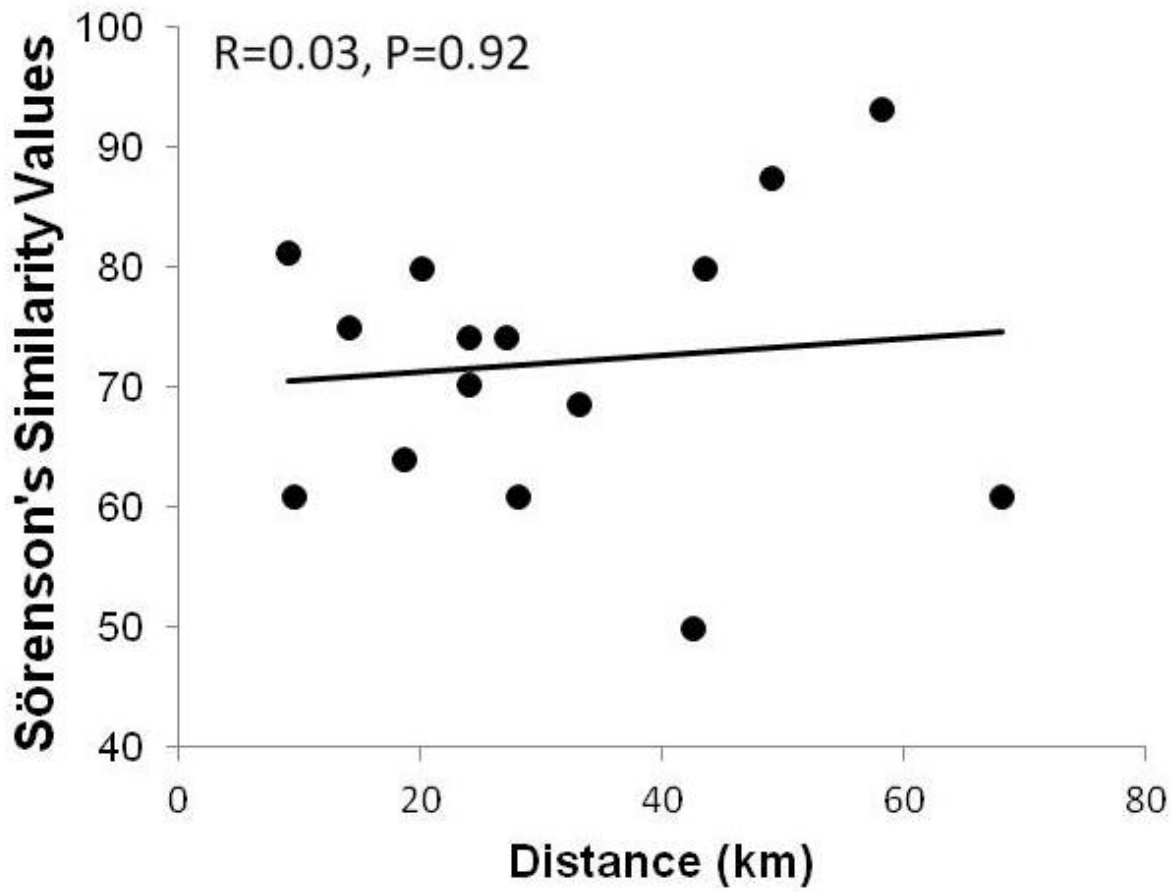


Figure 4. Spearman's correlation of Sørensen's similarity values for aquatic vegetation communities with linear distances (km) among the respective springs at Ozark National Scenic Riverways, 2007-2009.

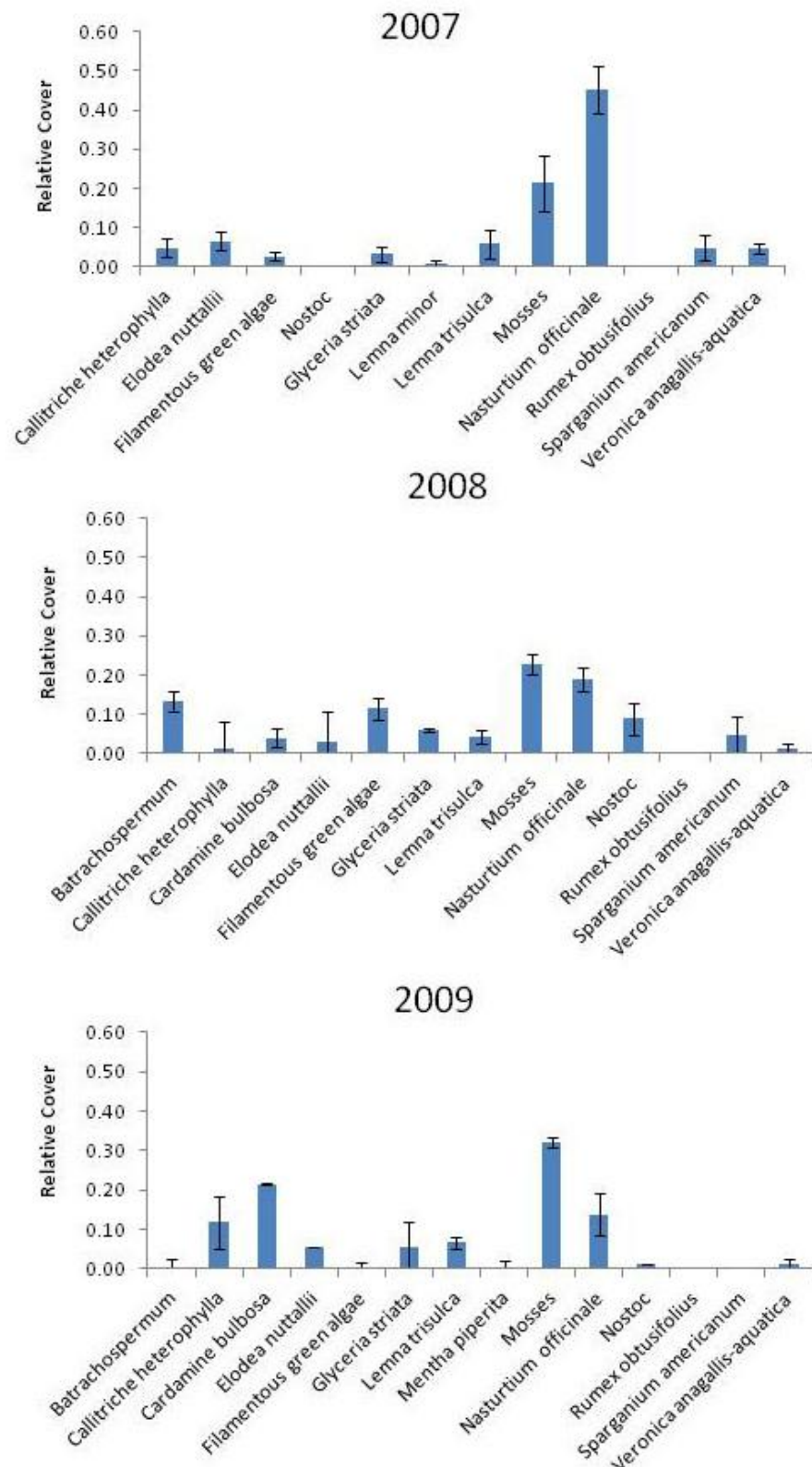


Figure 5. Mean taxa relative cover for aquatic vegetation collected at Alley Spring, OZAR, 2007-2009. Error bars represent 1 standard error.

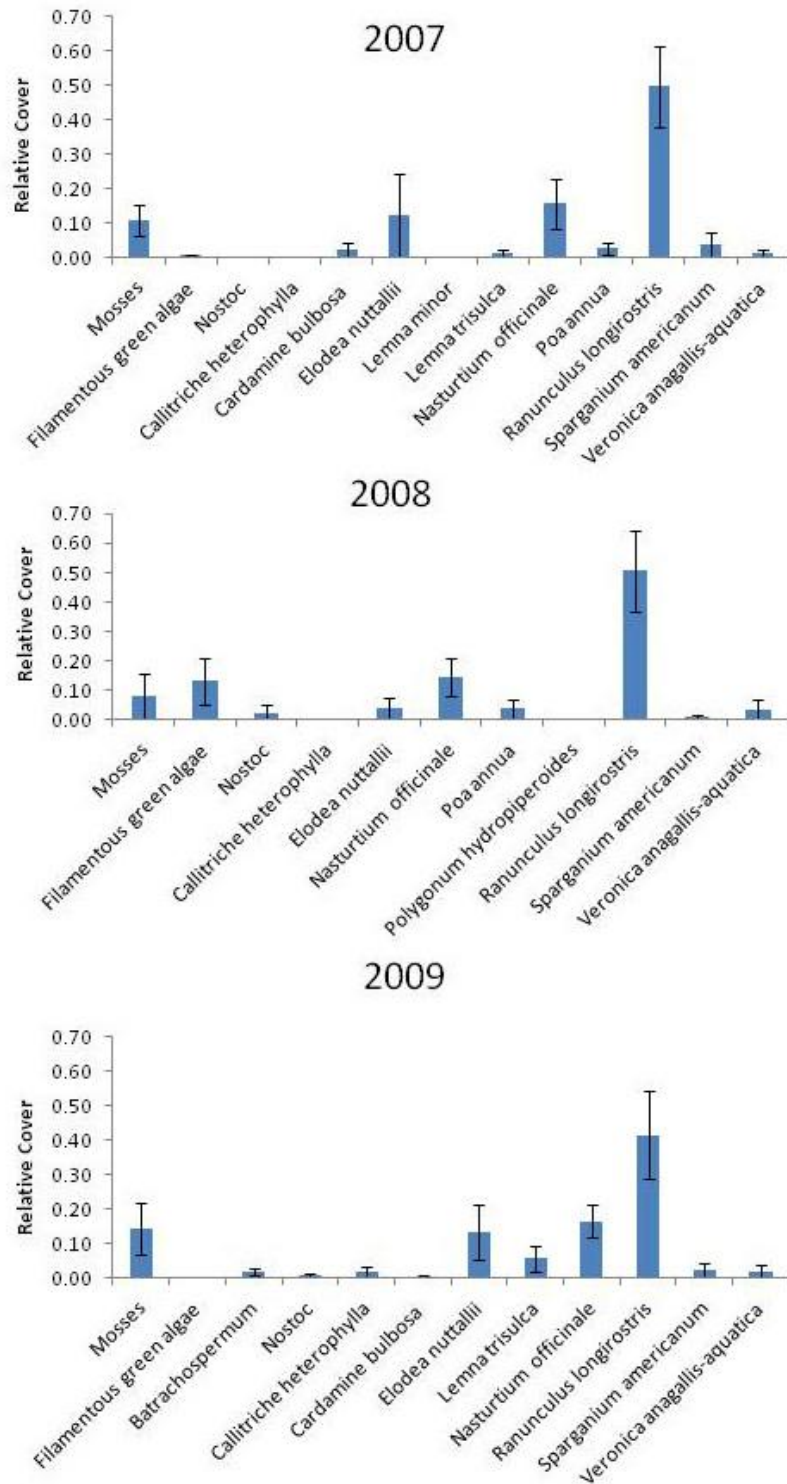


Figure 6. Mean taxa relative cover for aquatic vegetation collected at Big Spring, OZAR, 2007-2009. Error bars represent 1 standard error.

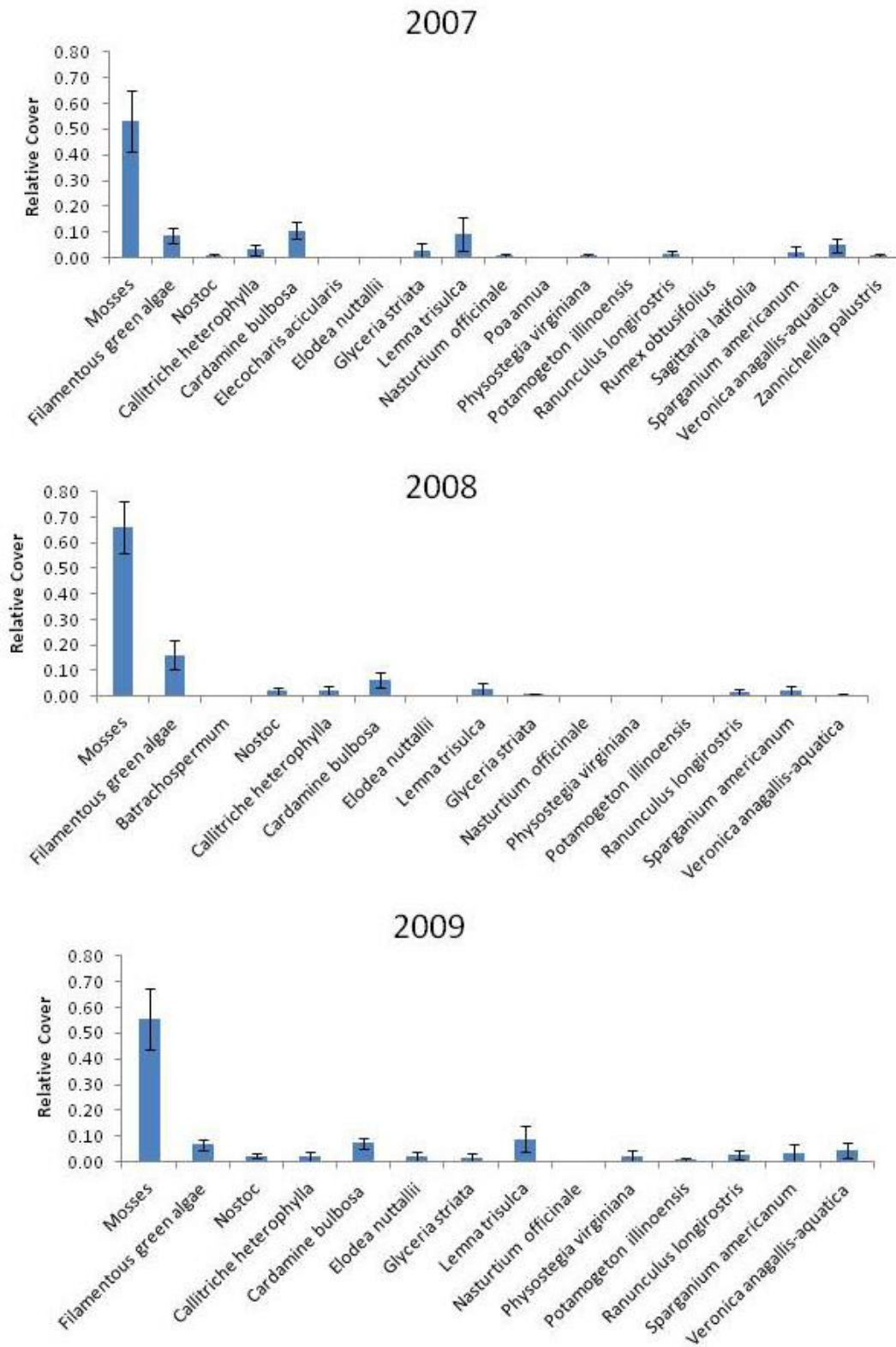


Figure 7. Mean taxa relative cover for aquatic vegetation collected at Blue Spring, OZAR, 2007-2009. Error bars represent 1 standard error.

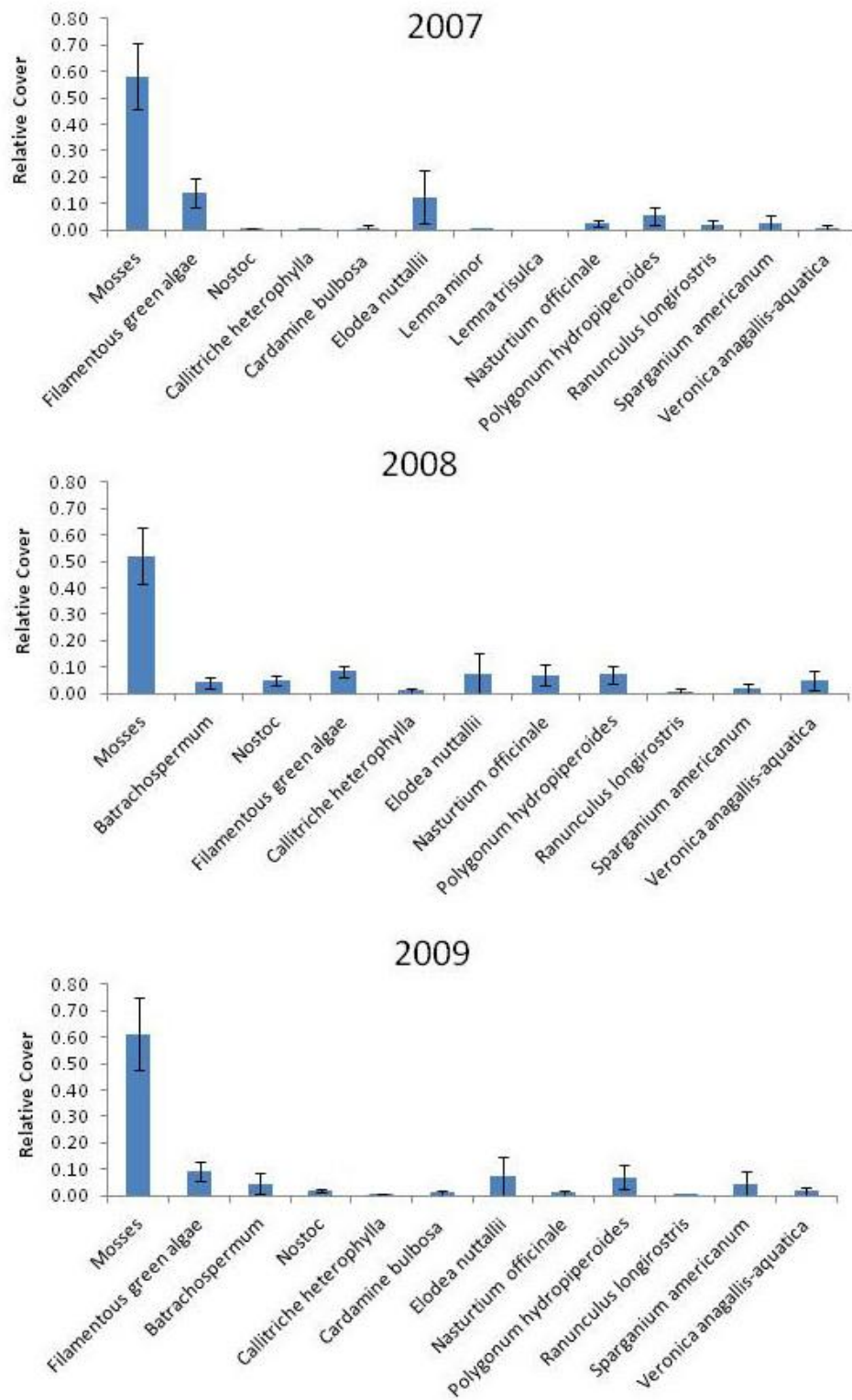


Figure 8. Mean taxa relative cover for aquatic vegetation collected at Pulltite Spring, OZAR, 2007-2009. Error bars represent 1 standard error.

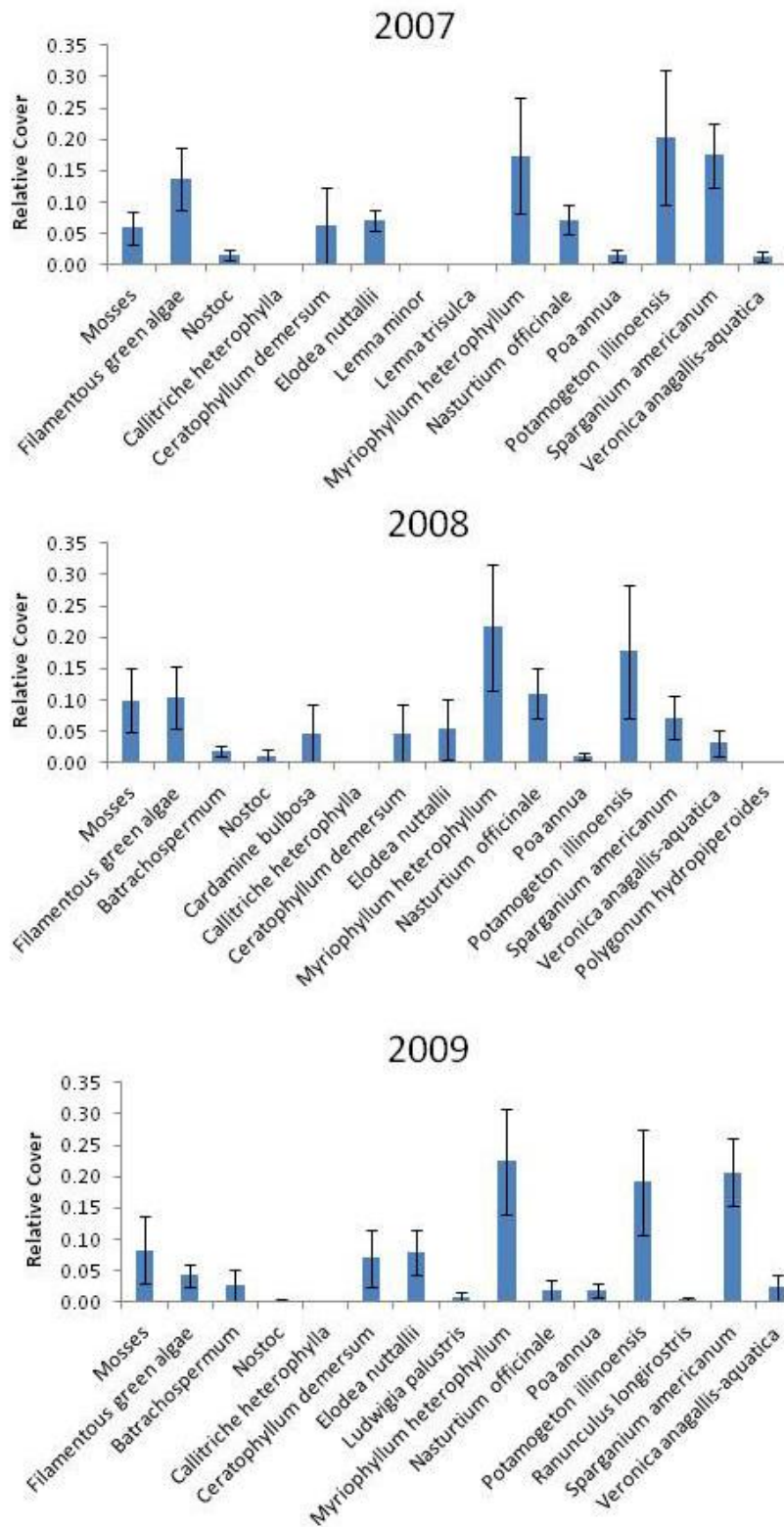


Figure 9. Mean taxa relative cover for aquatic vegetation collected at Round Spring, OZAR, 2007-2009. Error bars represent 1 standard error.

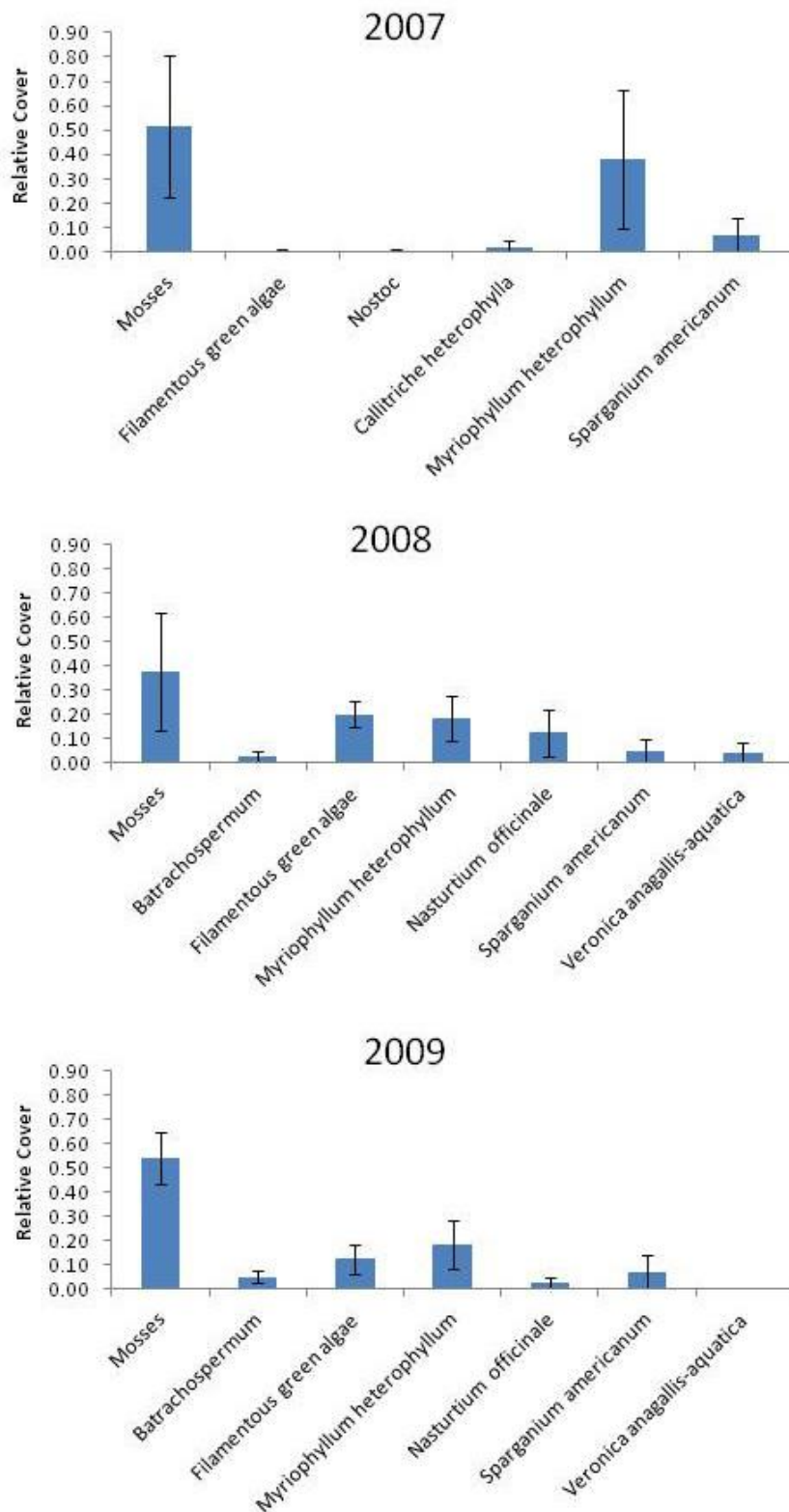


Figure 10. Mean taxa relative cover for aquatic vegetation collected at Welch Spring, OZAR, 2007-2009. Error bars represent 1 standard error.

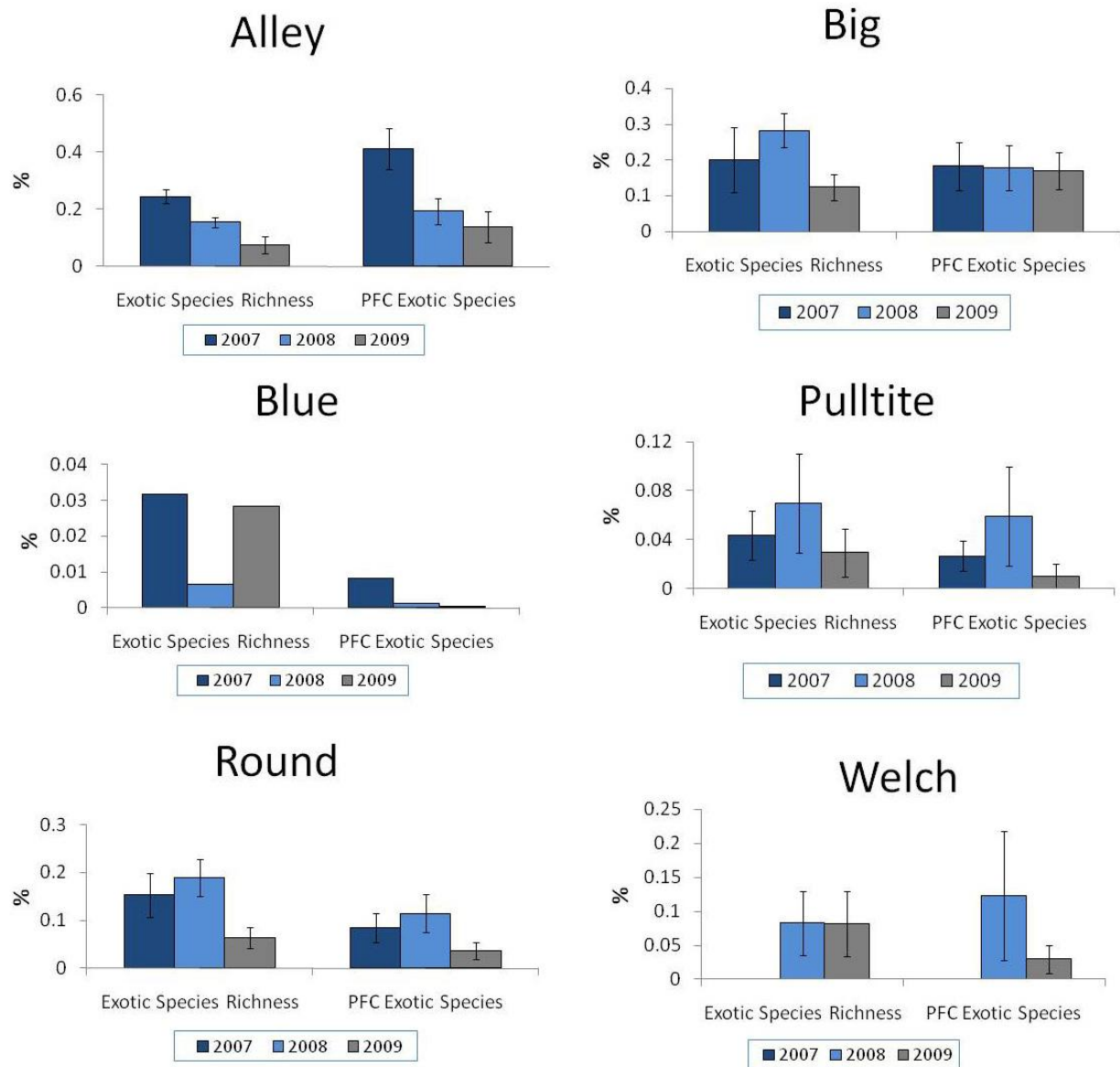


Figure 11. Ratio of the richness of exotic species and native species, and ratio of percent foliar cover (PFC) by exotic species and native species for the six large springs at OZAR, 2007-2009. Error bars represent 1 standard error.

Aquatic Invertebrates

Invertebrate assemblages among the springs include more than 66 genera from over 50 families. Aquatic invertebrate communities within the springs were dynamic among sampling years, and species richness was relatively low (<30 species) (Fig. 12). Alley Spring (~15-25 taxa) had the greatest taxa richness while Big Spring had the lowest richness (~12 taxa). Blue, Pulltite, Round, and Welch springs had similar taxa richness values (~15-20 taxa). The effective number of species derived from Shannon and Simpson index values were relatively low compared to taxa richness. This suggests the dominance of a few taxa because the effective number of species will approximate species richness when all taxa in a sample are equally abundant. The sensitive caddisfly genus, *Lepidostoma* (tolerance value=1) was among the most dominant taxa occurring in all of the springs. The percent dominant taxa (based on the top three most numerous taxa) typically comprised about 70% or greater of the community. Other common taxa occurring in samples included spring snail (*Amnicola*), water mites (“Hydracarina”), midges (Chironomidae), and amphipods (*Hyaella azteca*, *Crangonyx*, *Gammarus*).

The Hilsenhoff Biotic Index (HBI) was relatively low among samples and was generally below 5 (Fig. 13). Because HBI scores can range from 0 to 10 (with 10 indicating the most disturbance) the relatively low HBI scores for the springs indicate their water quality is good. Ephemeroptera, Trichoptera and Plecoptera (EPT) taxa richness was low in all springs (Fig. 13). Alley Spring had the greatest percentage of intolerant taxa (~60%), but all springs contained a modest percentage (~20-40%) of intolerant taxa (Fig.14). In all springs, a few taxa dominated their respective communities (Fig. 14).

There was a marked similarity in the invertebrate community structure among the respective spring with many species being shared in common (Table 7). Sørensen’s similarity values among springs ranged from 38% to over 69%. Big and Blue springs shared the most species in common (69.5%). Welch Spring shared the fewest species in common with the other springs, which may be due to its short (36 m) spring run, smaller sample size, and high current velocities that limit invertebrate colonization of the substrate. The degree of similarity of invertebrate communities in the springs was not correlated to linear distance (km) between individual springs (Fig. 15). This suggests that similarity is not driven by proximity of one spring to another, but by as yet undetermined environmental and habitat factors that occur in the springs. Dispersal among the springs via the river corridor is a viable possibility that was not evaluated for this report. Future analysis should evaluate biotic similarity among the springs along such pathways.

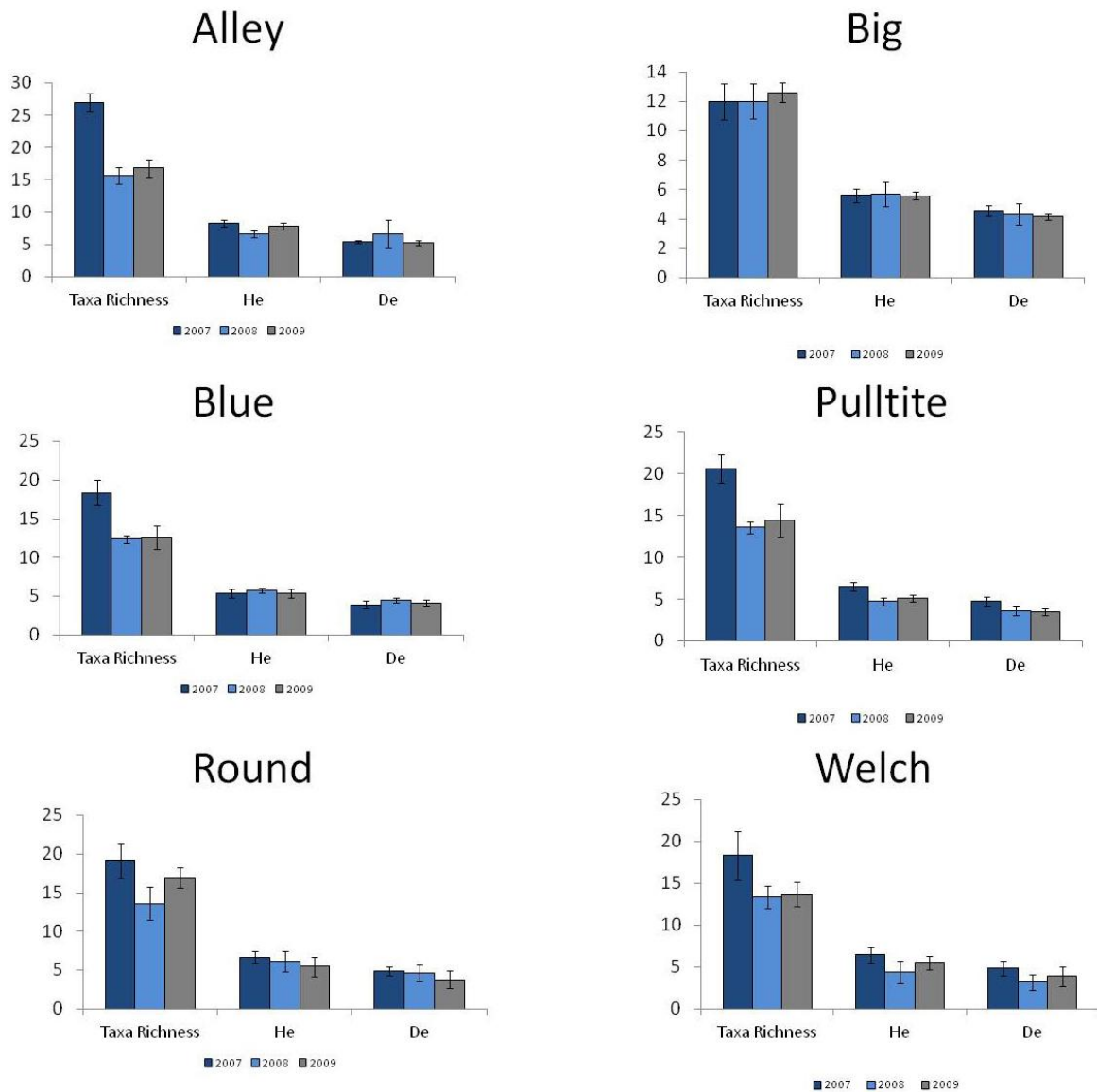


Figure 12. Diversity metrics for aquatic invertebrates collected at OZAR springs, 2007-2009. He=Shannon's index effective number, De=Simpson's index effective number. Error bars represent 1 standard error.

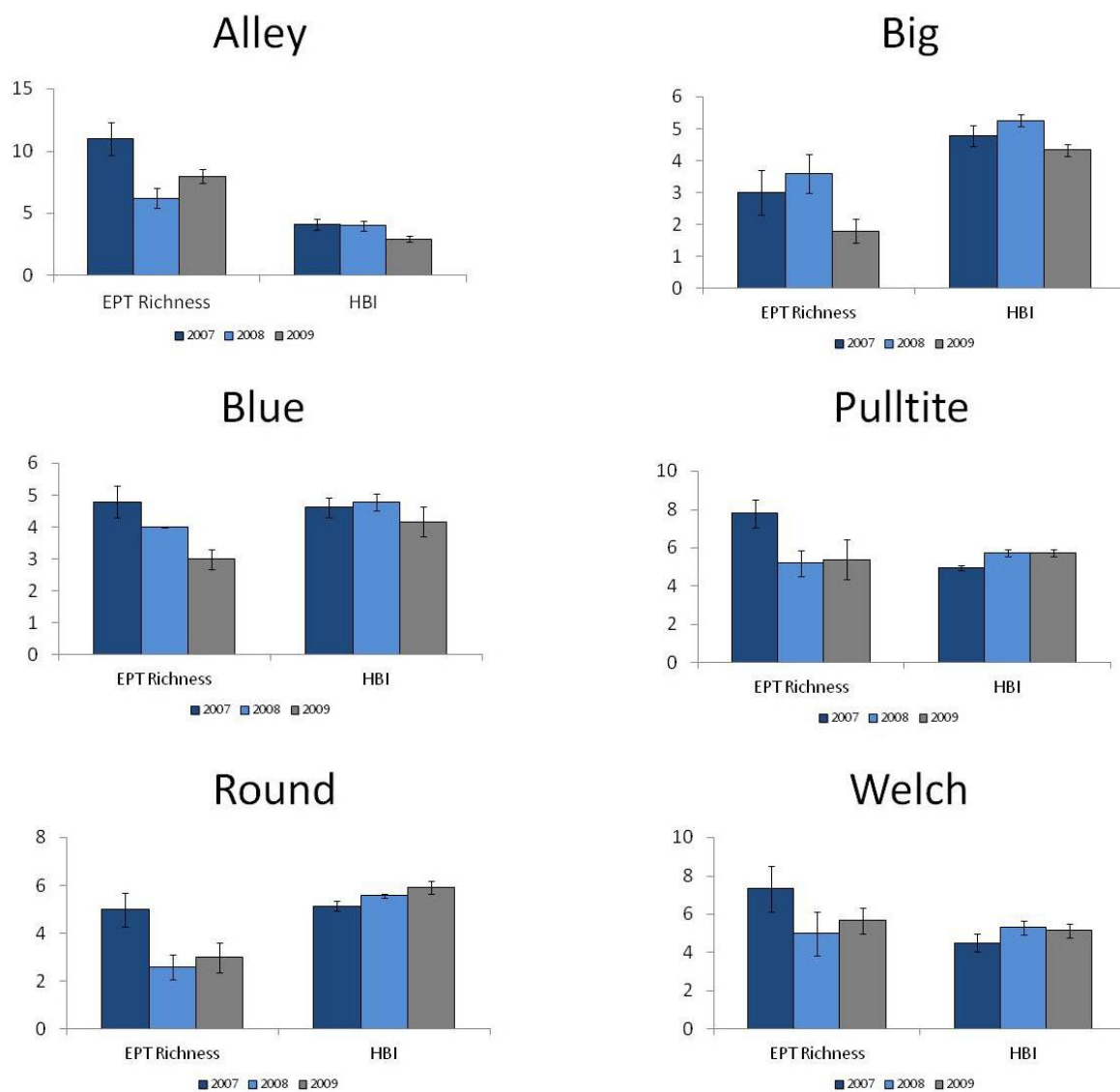


Figure 13. Ephemeroptera, Plecoptera, Trichoptera (EPT) richness and Hilsenhoff biotic index (HBI) for aquatic invertebrates collected at OZAR springs, 2007-2009. Error bars represent 1 standard error.

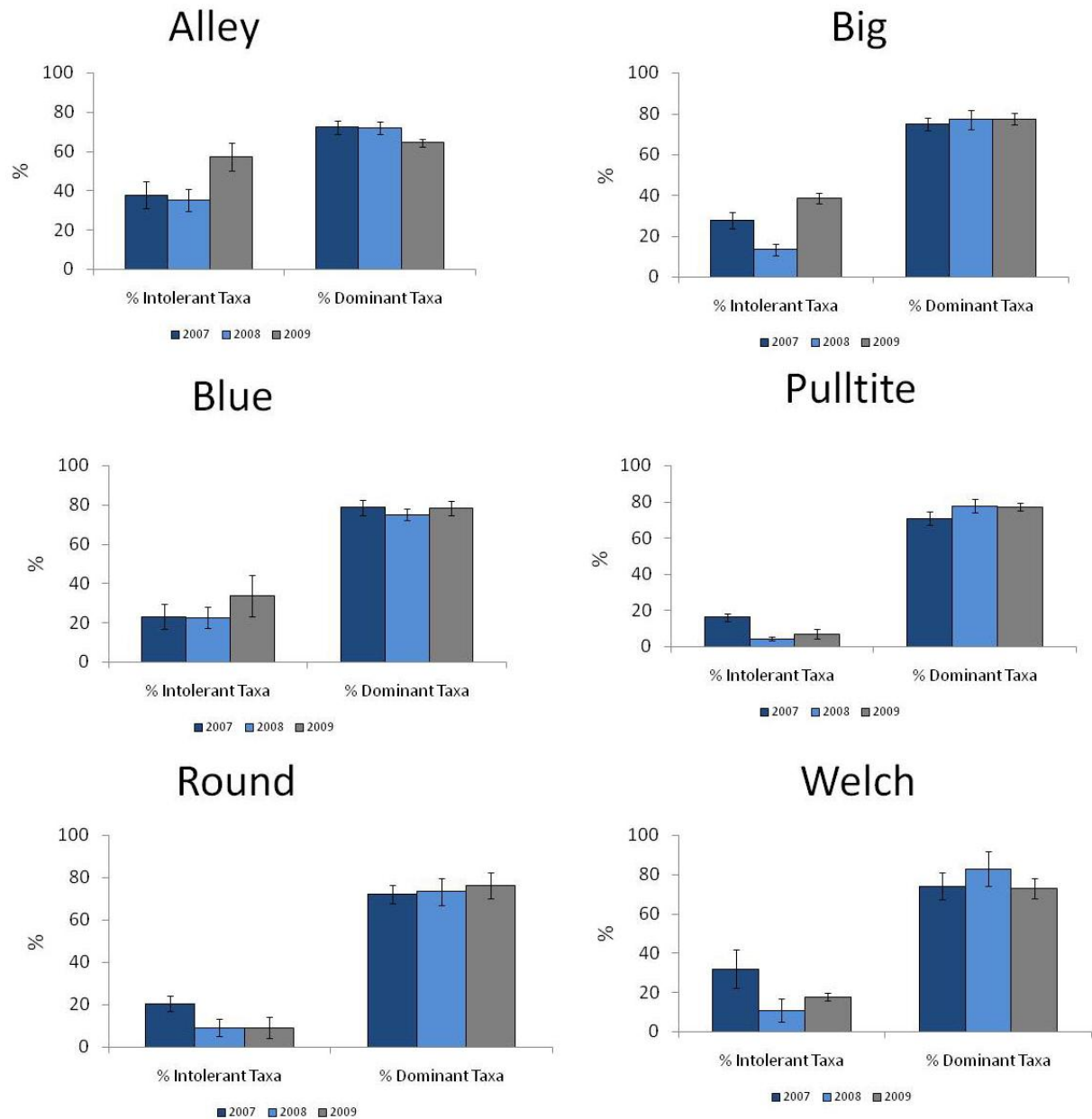


Figure 14. Percent intolerant taxa and percent dominant taxa in invertebrate samples collected from six large springs, OZAR, 2007-2009.

Table 7. Sørensen's percent similarity values for aquatic invertebrate communities occurring in large springs at Ozark National Scenic Riverways, 2007-2009.

	Big	Blue	Pulltite	Round	Welch
Alley	50.0	57.5	67.6	55.6	38
Big		69.5	54.9	57.6	46.5
Blue			59.6	55.3	48.9
Pulltite				54.2	48.1
Round					51.6

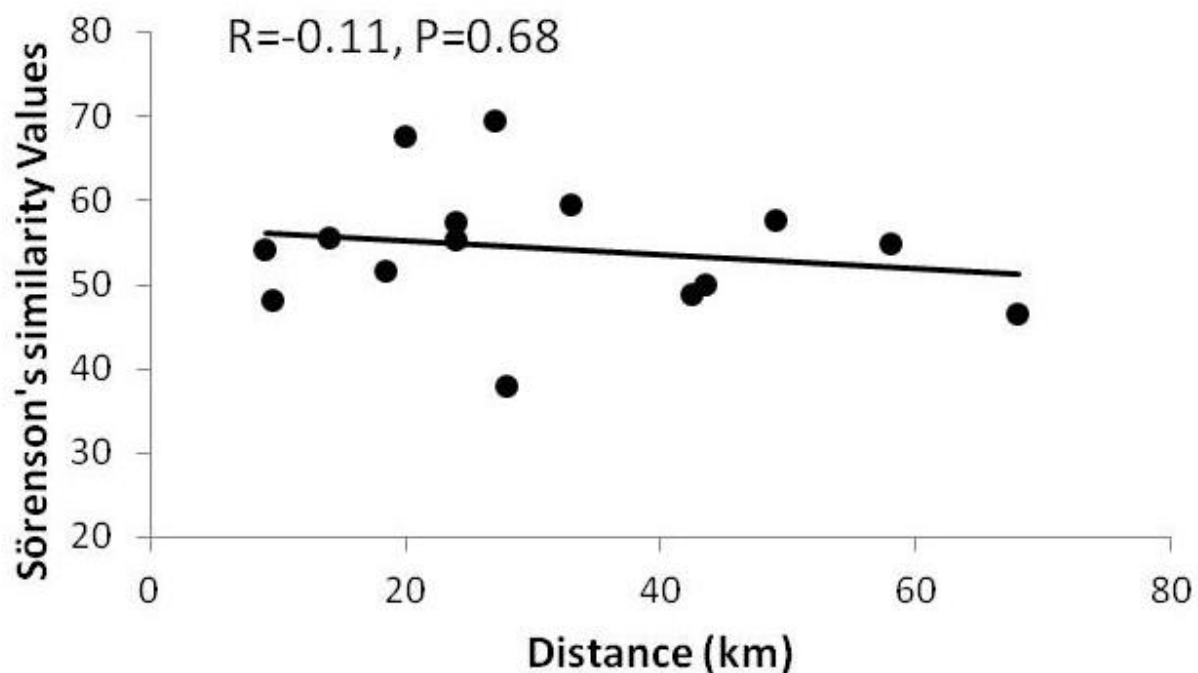


Figure 15. Spearman's correlation of Sørensen's similarity values for aquatic invertebrate communities with linear distances (km) among the respective springs at Ozark National Scenic Riverways, 2007-2009.

Fish

Number of fish species present in springs ranged from four to 12 species (Fig. 16, top panel), and abundance (catch per unit effort) ranged from two fish/min to nine fish/min (Fig. 15, bottom panel). Round, Big, and Alley springs had highest richness, number of lithophilic spawning species (species sensitive to siltation), and diversity (low Simpson's Index value) of the springs at OZAR (Fig. 16, top and middle panels). In contrast, Pulltite, Blue, and Welch springs showed lowest species richness and diversity but greatest abundance (Fig. 16, bottom panel).

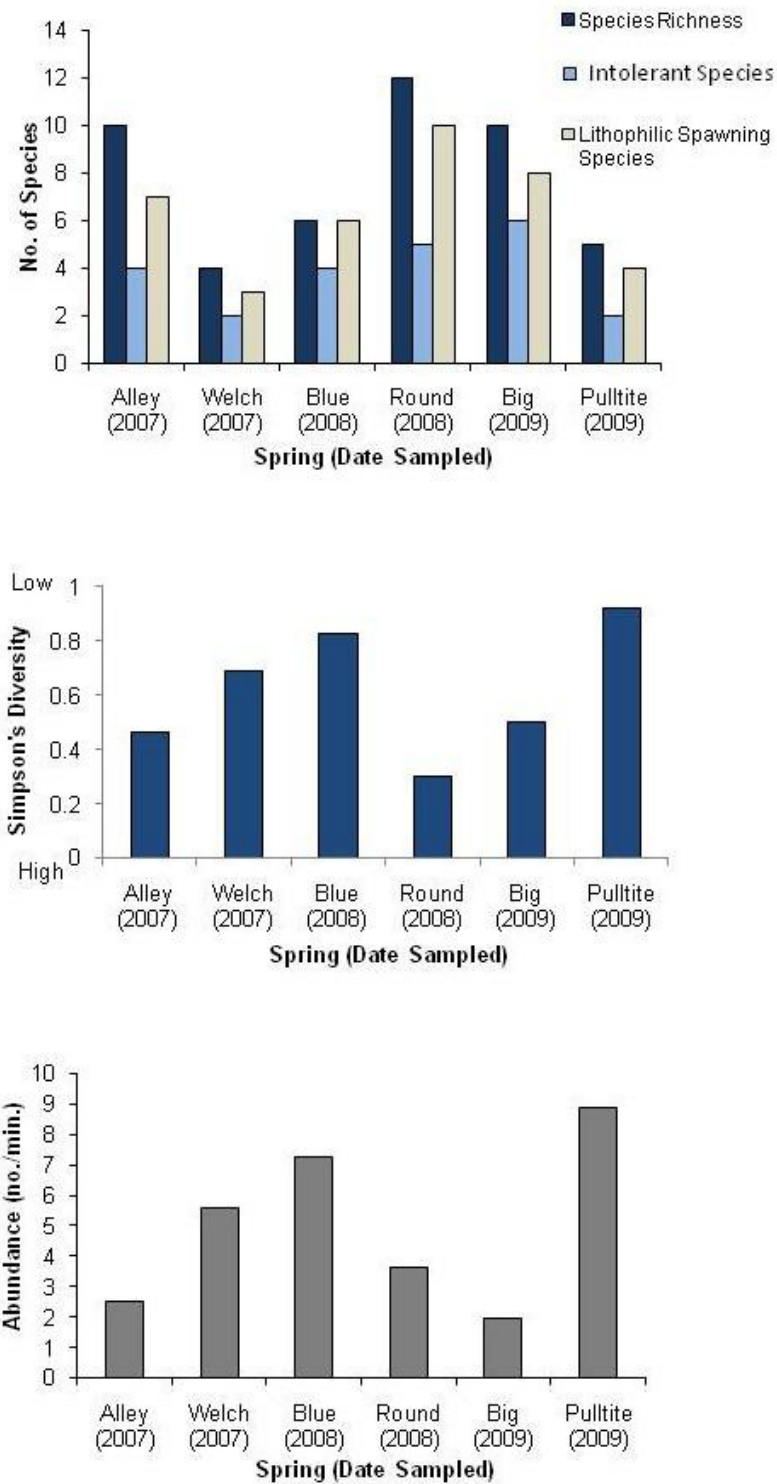


Figure 16. Richness metrics (top panel), diversity (middle panel), and abundance (bottom panel) of fish communities at six large springs at OZAR, 2007-2009.

Fish communities of most springs consisted largely of sculpin species (*Cottus* spp.; range 37-99%), a lithophilic spawning species that is sensitive to disturbance. Pulltite, Welch, and Blue springs, which had low richness and diversity, had a high percentage of their composition consisting solely of scuplins (91-99%). Those springs with relatively high richness and diversity also contained minnow species (Cyprinidae) and chain pickerel (*Esox niger*). Round Spring had a higher percent composition of bleeding shiner (*Luxilus zonatus*; 46%) and sculpins (37%) compared to the other springs.

Water Quality

Water quality data were similar among springs and years (Appendix B). Mean temperature among springs generally fell between 13.5-14.5 °C, and temperature was nearly constant with little observed diel fluctuation. Mean dissolved oxygen concentration in all of the springs was high, ranging from 8.2-11.1 mg/L. Dissolved oxygen concentration was usually highest in Welch Spring, likely owing to the turbulent nature of that spring. Specific conductance generally ranged between 200-350 µS/cm, and pH usually fell between 7.2-7.6. Turbidity was always at low levels in the springs with values normally less than 1 NTU and not exceeding 6 NTU for any spring or any year.

Habitat

Water depth, velocity, and width varied among springs, and to a lesser extent among years, but the high degree of overlap in standard errors of the mean within individual springs in most years suggest these differences would not be significant (Fig. 17). Big Spring was consistently the deepest (~80 cm) and widest (~30 cm) of the springs, while Blue and Pulltite springs were the shallowest (~21 cm and ~16 cm) and Alley Spring was the narrowest spring (~14 m). Current velocity was lowest at Round Spring but the most variable was Welch Spring, largely due to the strong eddy effects in that spring along the spring margins where the water flows upstream in some places.

Discharge varied among springs and years with Big Spring consistently having the highest flow and Round Spring consistently having the lowest flows among years (Table 8). Discharge for Round Spring in 2009 was higher than previous years due to heavy rainfall that occurred in its watershed prior to the sampling event.

Run habitat was dominant in all springs (Fig. 18). Big Spring had the largest percentage of run habitat (82-96%) within its spring branch. Although pool and riffle habitat were less common in springs, Round Spring generally had a higher percentage of pool habitat (15-48%) and Blue and Pulltite had higher percentage of riffle habitat (35-52% and 22-45%), when compared to other springs.

Table 8. Discharge for springs at Ozark National Scenic Riverways, 2007-2009.

Spring	2007	2008	2009
	(m ³ /s)		
Alley Spring	3.05	3.62	3.80
Big Spring*	13.93	13.54	11.78
Blue Spring	2.88	3.13	3.97
Pulltite Spring	1.11	2.21	1.63
Round Spring	0.63	0.88	2.99
Welch Spring	4.01	6.65	8.41
* Big Spring 2008 & 2009 values from USGS gauge No. 07067500			

Mean in-stream habitat parameters were dynamic among springs and sampling years (Fig. 19). Canopy cover for all of the springs was <40%, and periphyton generally was less than 25%. Filamentous algae also was generally 25% or less of cover with the dominant algae being red algae (Rhodophyta, *Batrachospermum*), generally considered intolerant of disturbance. Filamentous green algae (e.g., *Cladophora*) were occasionally represented in the springs, but at low levels and usually in marginal areas as opposed to the main channels. Aquatic vegetation was well represented in sample cells, typically exceeding 60% cover. Organic debris among springs was usually low ($\leq 20\%$), except for Round Spring, where organic debris ranged from 30-40% of the sampling area. The organic debris levels for Round Spring likely are due to the lower gradient and slower flows associated with this system as compared to the other springs.

Substrate among the springs varied considerably (Fig. 20). The substrate for Alley, Blue, Pulltite and Welch springs was predominantly Wentworth substrate categories 14-16 (large pebble-small cobble, 32-90 mm). The substrate of Big and Round springs generally contained smaller mean substrate sizes compared to the other springs, as well as a wide range of substrate sizes ranging from sands and gravels to cobble and boulders. Embeddedness was generally around 25-30% for most springs, except for Big and Round springs, where the small substrate sizes in those two springs resulted in high embeddedness (Fig. 21). Embeddedness was negatively correlated ($r = -0.64$) with substrate size, decreasing as a function of increasing substrate size (Fig. 22).

Fish cover and bank vegetation were assessed during years in which fish communities were sampled within the spring (Alley and Welch in 2007, Blue and Round in 2008, Big and Pulltite 2009). Because several cover types may be present at a transect, the percentages given are the percent of a reach that contains each cover type; therefore, percentages do not add to 100% for the reach. Small woody debris was common in most springs, ranging from 25% cover in Welch Spring to 48% in Alley and Big springs (Fig. 23). Overhanging vegetation was abundant at Pulltite Spring (58%), and Big Spring had 30% cover of tree roots along the banks. Percentage of area without fish cover ranged from 36-55%. Banks along the spring branches were dominated by mature trees (36-86%) and small trees and shrubs (41-86%; Fig. 22). Big, Pulltite, and Welch also had a high percent of grass cover (73%, 64%, and 67%, respectively) along the banks.

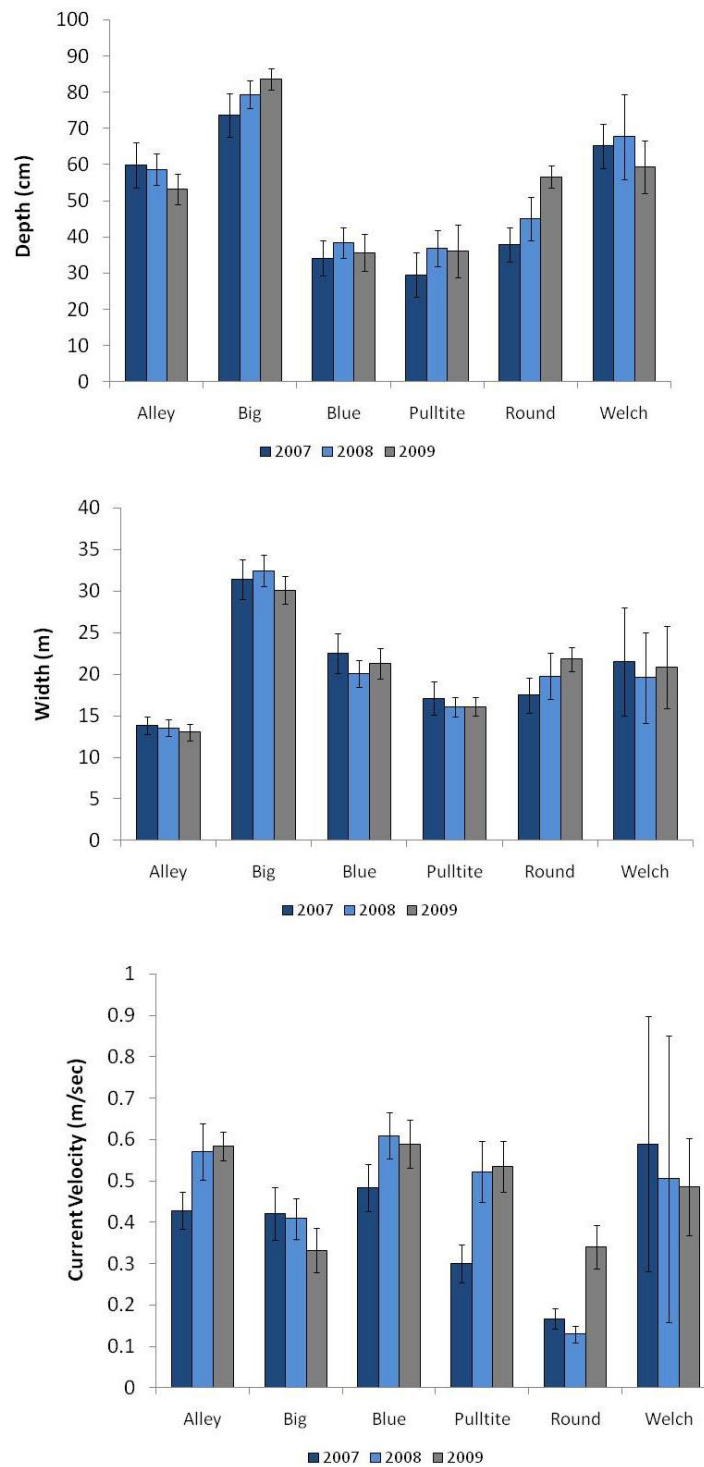


Figure 17. Mean and 1 standard error for depth, current velocity, width and substrate for six large springs at OZAR, 2007-2009.

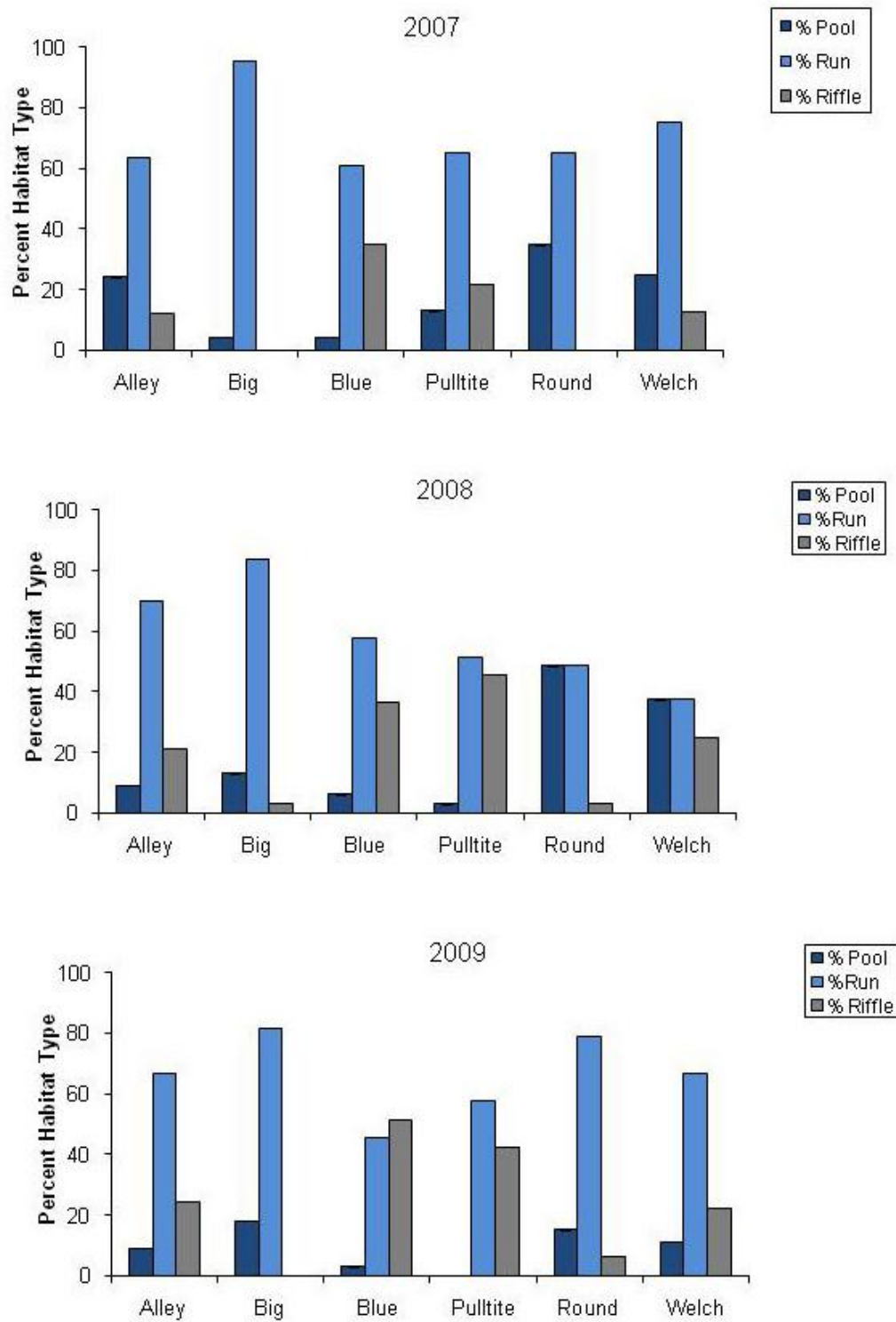


Figure 18. Percent of habitat types in six large springs at OZAR, 2007-2009.

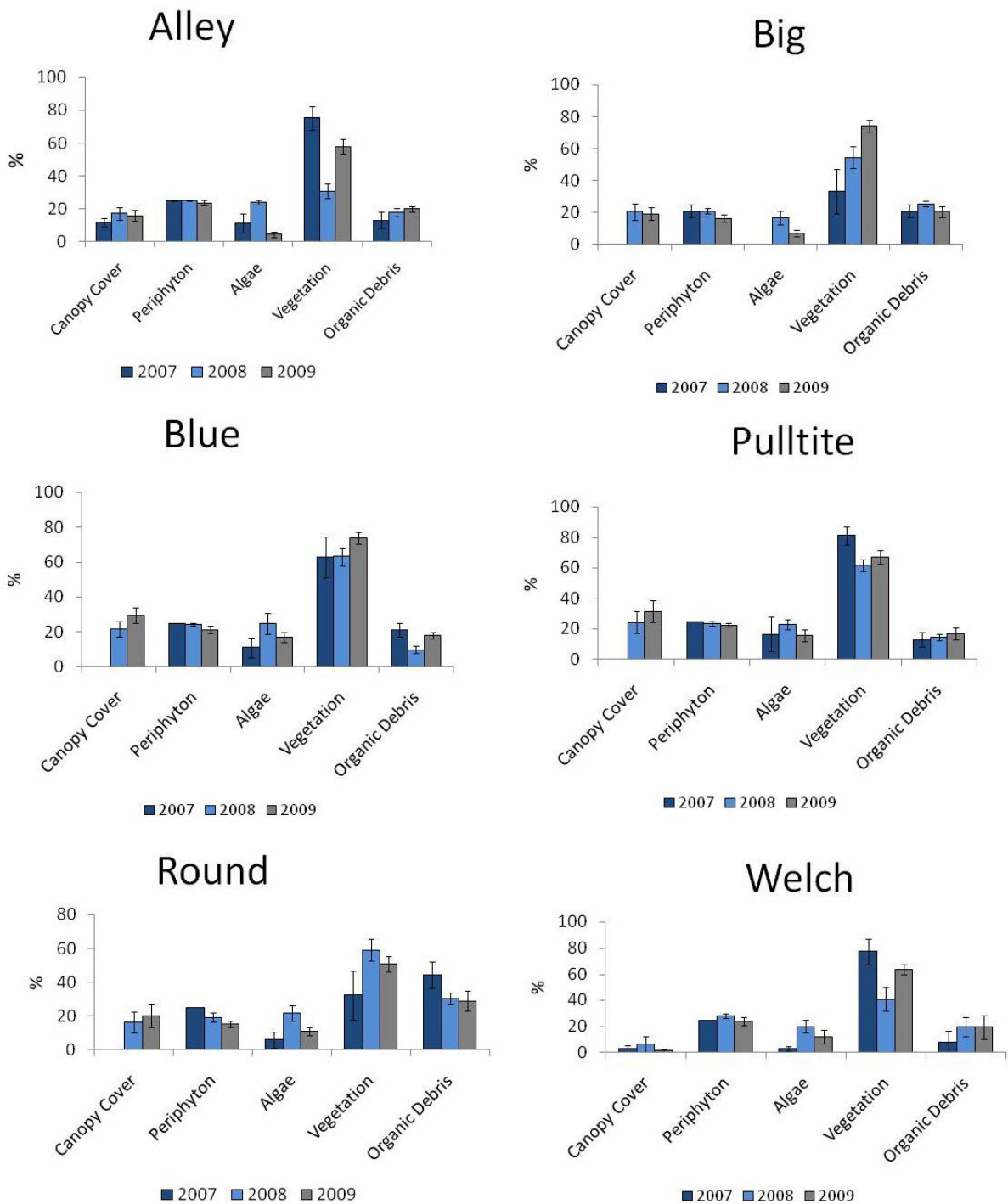


Figure 19. Percent coverage of instream habitat parameters for six large springs at OZAR, 2007-2009. Error bars represent 1 standard error.

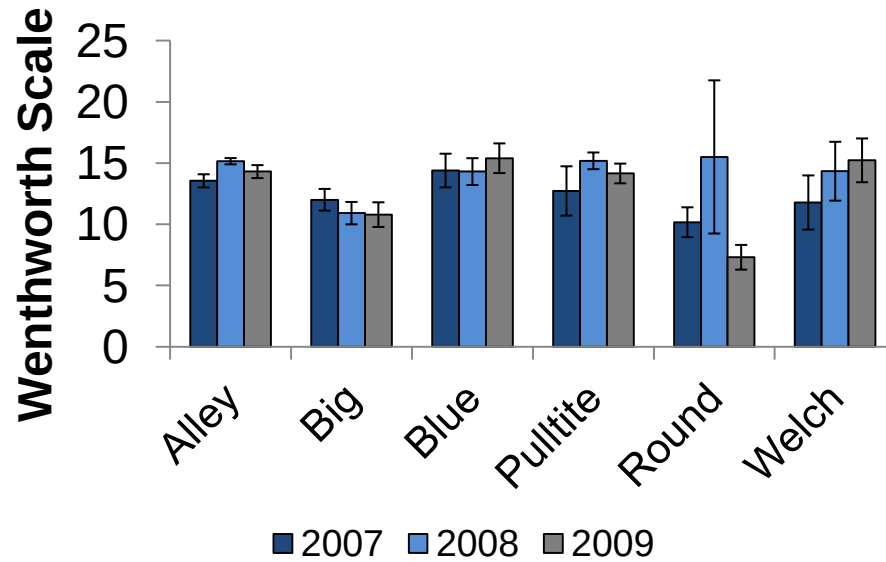


Figure 20. Dominant substrate size among springs at OZAR, 2007-2009. Error bars represent 1 standard error.

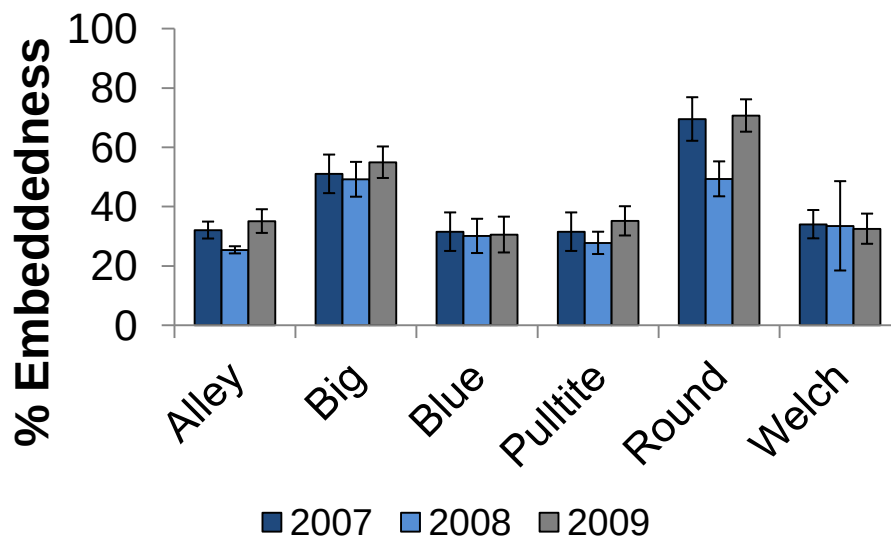


Figure 21. Percentage substrate embeddedness among springs at OZAR, 2007-2009. Error bars represent 1 standard error.

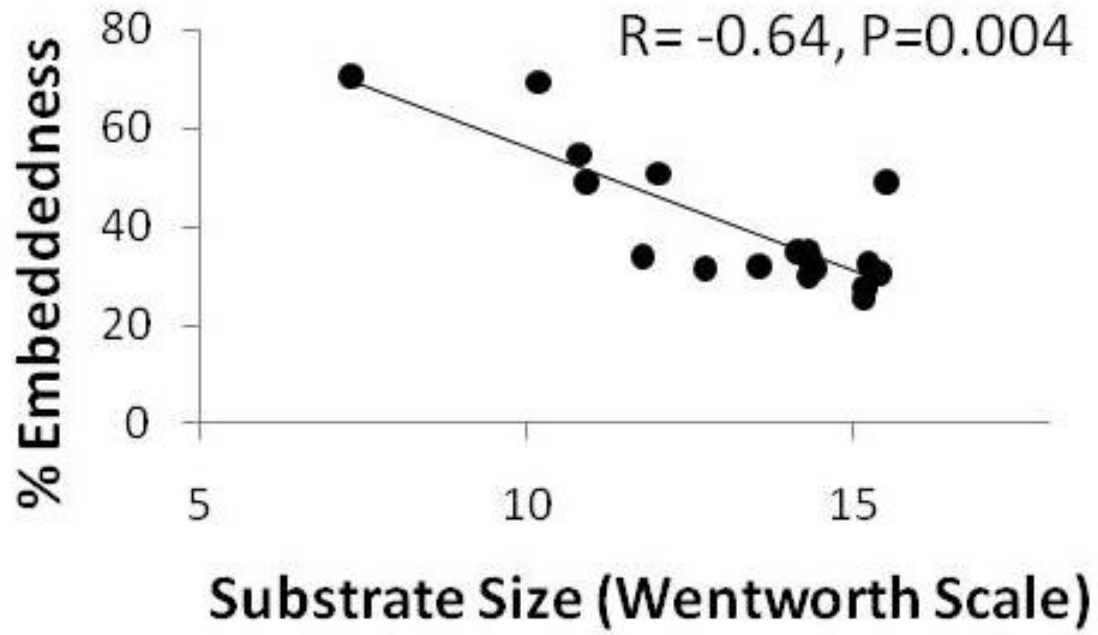


Figure 22. Relationship of substrate size to embeddedness among all springs at OZAR.

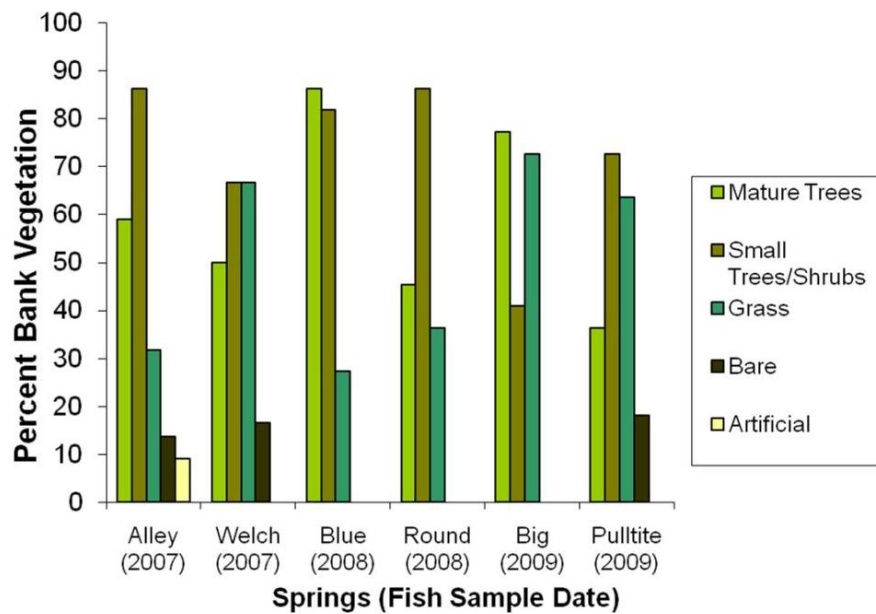
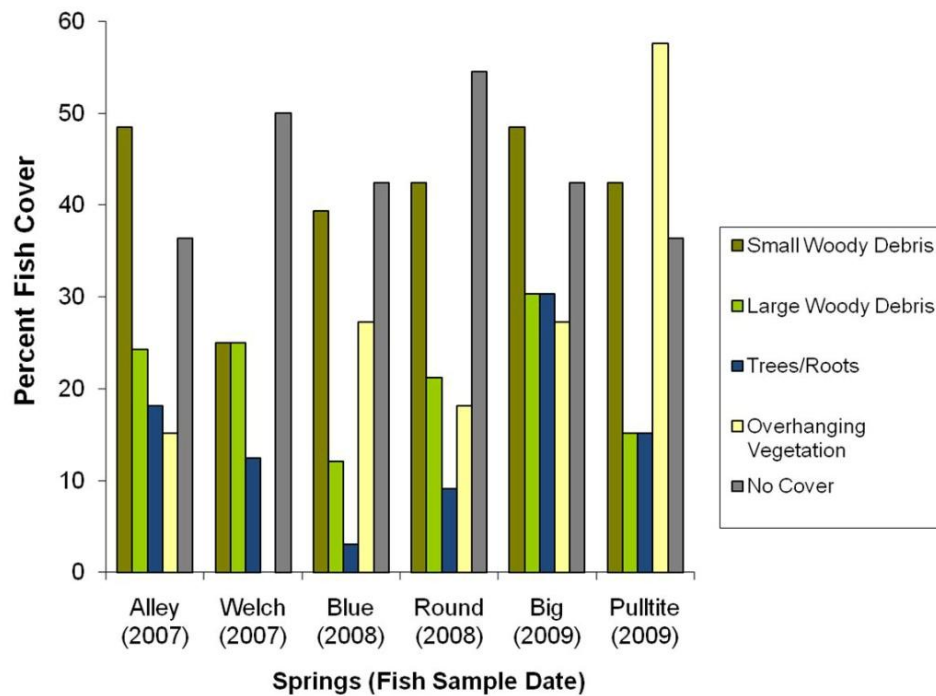


Figure 23. Percentage of fish cover and bank vegetation types within springs in years where fish sampling was conducted. Percentages for a spring do not add to 100% because multiple cover types were present at each transect within the reach.

Discussion

Habitat conditions within a spring depend on groundwater sources and a matrix of other factors (Williams and Danks, 1991). Because of their unique and independent sources, springs typically have a mosaic structure, a high degree of individuality, and typically an azonal character attributed to their physiochemical stability (Cantonati *et al.*, 2006). The monitoring results presented here support that assessment.

The dynamic diversity of aquatic vegetation in the springs was not unexpected. Currier (1990a, b) reported that the plant community structure in several springs had changed since Steyermark studied those communities in the 1940s (Steyermark 1941), with some species apparently disappearing and others documented for the first time. For example, Currier (1990b) noted that horned pondweed (*Zannichellia palustris*), leafy pondweed (*Potamogeton foliosus*), and submerged stands of the non-native annual bluegrass (*Poa annua*) documented in Steyermark's study of Big Spring were not documented in his study. Lipscomb (undated) found these three species were present. Conover (1994) focused on three common species occurring in Big Spring and did not conduct a complete inventory of the vegetation. Our study also showed that *P. annua* still occurs in Big Spring, but no representatives of leafy pondweed were found. Steyermark (1941) did not record star duckweed (*Lemna trisulca*) or longbeak buttercup (*Ranunculus longirostris*) from Big Spring, but these species are now present and abundant there (Currier, 1990b; Lipscomb, undated; this study). Our data show that some species, such as swamp smartweed (*Polygonum hydropiperoides*) at Pulltite Spring, have made substantial increases in their foliar coverage since monitoring was initiated while others have decreased. Only additional monitoring will allow insight into any patterns that may exist among aquatic vegetation structure dynamics in these springs.

Although numerous studies have addressed aquatic invertebrates at OZAR, the invertebrate communities of the large springs have been largely unstudied. Nielsen (1996) studied the substrate association by invertebrates in Big Spring, and Dr. Charlie Rabeni and associates at the University of Missouri collected and analyzed invertebrates from the springs in support of protocol development. The data in both studies are similar to the data reported here. The invertebrate fauna occurring in all of the springs is presently dominated by environmentally sensitive taxa. Although the percentage of intolerant invertebrate taxa among springs was moderate ($\leq 40\%$) these taxa typically were the most numerically dominant accounting for $\geq 70\%$ of the total density. This finding also was demonstrated in the relatively low HBI scores for each site. The dominance of intolerant taxa, and mainly representatives of the caddisfly genus, *Lepidostoma* (tolerance value = 1), occurring in the springs indicates their respective water quality conditions are good. Although these findings indicate the water quality and habitat conditions in the springs are high quality, there presently are insufficient data from which to base any specific conclusions on invertebrate community structure and dynamics in the springs. Additional monitoring may allow insight into possible patterns that may exist in and community structure in these springs.

Fish communities consisted largely of species sensitive to poor water quality conditions and siltation. Knobfin sculpin (*Cottus hypselurus*) and banded sculpin (*Cottus carolinae*) were the dominant species in most springs, with the exception of Round Spring, which consisted largely

of bleeding shiners. Both sculpin species and bleeding shiners are lithophilic spawners, requiring clean gravel and cobble substrates and high dissolved oxygen levels. Species richness was higher at Round and Big springs, where slower flowing habitats (pools) and a variety of substrate sizes were available for fish. Alley Spring, which also had high fish richness, showed a larger variety of substrates and percent pool habitat in the year in which fish were sampled. In contrast, fish abundance was higher at Blue, Pulltite, and Welch springs, which typically had faster flows and predominately run and riffle habitats, as well as less diversity of substrate sizes available. Although only one year of fish data has been collected for each spring, our study demonstrates the possible influence of physical habitat on spring fish communities.

Fish species richness, diversity, and number of lithophilic spawning species were higher at Round, Big, and Alley springs, possibly due to the availability of slower flowing habitat than that typical of the other springs. In years when these springs were sampled for fish, average velocity was slower (range of 0.13 – 0.43 m/s), a higher percent of pool habitats were available in these springs (range of 18-48%), and a larger range of substrates (silt/sand to cobble) were present. Alley Spring also had the highest richness and diversity of aquatic vegetation and invertebrate taxa; Big Spring had low richness and diversity of vegetation and invertebrates, possibly due to the sandy substrate more commonly found in the spring. Fish abundance was higher at Blue, Pulltite, and Welch springs than at the other springs. These springs had faster average velocities (range 0.59-0.64 m/s) and higher percent of riffle habitats (range of 11- 42%) compared to the other springs in years when fish were sampled.

The preliminary findings presented here reflect the broad natural habitat diversity, and physical and chemical stability in these springs. Geographic location of the springs does not appear to be a primary contributing factor in the composition of their respective vegetation, invertebrate, or fish communities. The three years of data presented here suggest that physical habitat factors including flow, substrate size and diversity, and distribution and diversity of aquatic vegetation may play a primary role in structuring these communities. However, collecting and analyzing additional monitoring data are required to determine the importance of these factors and elucidate other unknown parameters that may be important for spring communities.

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Appendix A.

Table A-1. Diversity data on aquatic vegetation occurring in six large springs at OZAR, 2007-2009. Values for each species entry are means (top row) and standard errors (bottom row). ISF=individual species frequency, PFC=percent foliar cover, SRC=species relative cover, SRF=species relative frequency, SIV=species importance value. Species in bold font are not native to the springs.

Spring	Metric				
Alley 2007	ISF	PFC	SRC	SRF	SIV
<i>Callitriche heterophylla</i>	55.56	4.06	0.05	0.13	9.16
	14.06	1.62	0.02	0.03	2.48
<i>Elodea nuttallii</i>	22.22	6.25	0.06	0.06	6.34
	11.11	2.72	0.02	0.03	2.27
Filamentous green algae	44.44	2.53	0.03	0.10	6.39
	14.06	1.04	0.01	0.03	1.92
<i>Nostoc</i>	11.11	0.06	0.00	0.02	1.14
	11.11	0.06	0.00	0.02	1.14
<i>Glyceria striata</i>	27.78	2.67	0.03	0.06	4.71
	10.24	1.67	0.02	0.02	1.90
<i>Lemna minor</i>	5.56	0.83	0.01	0.02	1.14
	5.56	0.83	0.01	0.02	1.14
<i>Lemna trisulca</i>	33.33	4.78	0.06	0.08	6.92
	14.91	2.75	0.04	0.04	3.69
Mosses	77.78	18.44	0.21	0.19	20.28
	16.48	6.97	0.07	0.04	4.76
<i>Nasturtium officinale</i>	83.34	37.78	0.45	0.21	33.33
	7.45	6.13	0.06	0.02	4.11
<i>Rumex obtusifolius</i>	5.56	0.03	0.00	0.01	0.65
	5.56	0.03	0.00	0.01	0.65
<i>Sparganium americanum</i>	11.11	4.31	0.05	0.04	4.14
	7.03	3.40	0.03	0.02	2.65
<i>Veronica anagallis-aquatica</i>	27.78	3.50	0.05	0.07	5.79
	5.56	0.96	0.01	0.02	1.46
2008					
<i>Batrachospermum</i>	72.22	5.58	0.13	0.12	12.70
	13.38	1.67	0.03	0.02	2.19
<i>Callitriche heterophylla</i>	38.89	0.72	0.01	0.05	3.30
	5.56	4.42	0.07	0.02	4.21
<i>Cardamine bulbosa</i>	55.56	2.28	0.04	0.09	6.38
	7.03	1.75	0.02	0.02	2.00
<i>Elodea nuttallii</i>	22.22	1.72	0.03	0.03	2.96
	15.91	2.44	0.08	0.03	5.47

Spring	Metric				
2008	ISF	PFC	SRC	SRF	SIV
Filamentous green algae	88.89	6.92	0.11	0.16	13.72
	8.61	1.47	0.03	0.02	1.92
<i>Glyceria striata</i>	22.22	3.39	0.06	0.04	4.80
	13.38	0.33	0.01	0.02	1.10
<i>Lemna trisulca</i>	27.78	2.69	0.04	0.04	4.08
	7.03	1.04	0.02	0.01	1.20
Mosses	94.45	13.92	0.23	0.17	19.82
	14.06	1.59	0.03	0.02	2.04
<i>Nasturtium officinale</i>	77.78	10.72	0.19	0.14	16.34
	11.11	1.66	0.03	0.02	1.80
Nostoc	66.67	4.75	0.09	0.12	10.21
	7.03	2.55	0.04	0.01	2.00
<i>Rumex obtusifolius</i>	5.56	0.17	0.00	0.01	0.55
	5.56	0.17	0.00	0.01	0.55
<i>Sparganium americanum</i>	11.11	3.47	0.05	0.02	3.16
	7.03	3.47	0.05	0.01	2.69
<i>Veronica anagallis-aquatica</i>	16.67	1.00	0.01	0.02	1.86
	7.45	0.82	0.01	0.01	0.95
2009					
<i>Batrachospermum</i>	11.11	0.03	0.00	0.02	0.83
	7.45	2.18	0.03	0.01	1.35
<i>Callitriche heterophylla</i>	88.89	8.78	0.12	0.16	13.80
	7.03	4.95	0.07	0.01	3.74
<i>Cardamine bulbosa</i>	100.00	14.61	0.22	0.19	20.02
	10.24	0.06	0.00	0.03	1.41
<i>Elodea nuttallii</i>	44.45	4.36	0.06	0.07	6.38
	7.03	0.03	0.00	0.01	0.53
Filamentous green algae	27.78	0.17	0.00	0.06	2.89
	14.06	0.99	0.01	0.02	1.54
<i>Glyceria striata</i>	38.89	4.36	0.06	0.07	6.09
	0.00	3.02	0.06	0.02	3.95
<i>Lemna trisulca</i>	83.34	5.28	0.07	0.15	10.83
	7.03	1.53	0.02	0.01	0.68
<i>Mentha piperita</i>	0.00	0.03	0.00	0.00	0.02
	11.11	1.46	0.02	0.02	1.67
Mosses	88.89	23.28	0.32	0.16	24.11
	10.24	0.89	0.01	0.02	1.44
<i>Nasturtium officinale</i>	33.33	10.56	0.14	0.06	9.81
	17.21	3.97	0.05	0.03	3.84
Nostoc	22.22	1.06	0.01	0.03	2.30
	0.00	0.03	0.00	0.00	0.02
<i>Rumex obtusifolius</i>	5.56	0.03	0.00	0.01	0.57
	5.56	0.03	0.00	0.01	0.57
<i>Sparganium americanum</i>	0.00	0.17	0.00	0.00	0.10
	0.00	0.17	0.00	0.00	0.10

Spring	Metric				
2009	ISF	PFC	SRC	SRF	SIV
<i>Veronica anagallis-aquatica</i>	22.22	1.06	0.01	0.03	2.30
	14.06	0.99	0.01	0.02	1.54
Big 2007					
<i>Lemna minor</i>	5.56	0.03	0.00	0.02	1.23
	5.56	0.03	0.00	0.02	1.23
<i>Lemna trisulca</i>	11.11	1.00	0.01	0.03	2.39
	7.03	0.82	0.01	0.02	1.51
Mosses	55.56	6.11	0.11	0.20	15.23
	16.48	2.52	0.05	0.06	4.50
Filamentous green algae	16.67	0.22	0.01	0.06	3.48
	11.39	0.19	0.00	0.05	2.59
<i>Nostoc</i>	5.56	0.03	0.00	0.02	1.06
	5.56	0.03	0.00	0.02	1.06
<i>Callitriche heterophylla</i>	5.56	0.17	0.00	0.01	0.81
	5.56	0.17	0.00	0.01	0.81
<i>Cardamine bulbosa</i>	11.11	0.86	0.02	0.04	3.30
	7.03	0.83	0.02	0.03	2.28
<i>Elodea nuttallii</i>	22.22	4.94	0.12	0.08	10.01
	11.11	4.71	0.12	0.05	8.07
<i>Nasturtium officinale</i>	50.00	11.97	0.16	0.17	16.46
	18.76	5.95	0.07	0.06	6.67
<i>Poa annua</i>	11.11	1.67	0.03	0.03	2.82
	7.03	1.05	0.02	0.02	1.80
<i>Ranunculus longirostris</i>	77.78	34.78	0.50	0.27	38.59
	16.48	8.29	0.12	0.07	8.81
<i>Sparganium americanum</i>	5.56	2.08	0.04	0.02	2.67
	5.56	2.08	0.04	0.02	2.67
<i>Veronica anagallis-aquatica</i>	11.11	0.86	0.01	0.03	1.96
	11.11	0.86	0.01	0.03	1.96
2008					
Mosses	5.56	5.42	0.08	0.02	5.09
	5.56	5.42	0.08	0.02	5.09
Filamentous green algae	61.11	3.01	0.13	0.23	17.83
	15.91	1.41	0.08	0.06	6.37
<i>Nostoc</i>	11.11	1.67	0.02	0.05	3.58
	11.11	1.67	0.02	0.05	3.58
<i>Callitriche heterophylla</i>	11.11	0.06	0.00	0.04	2.06
	7.03	0.04	0.00	0.03	1.33
<i>Elodea nuttallii</i>	5.56	3.47	0.04	0.02	2.68
	5.56	3.47	0.04	0.02	2.68
<i>Nasturtium officinale</i>	63.89	6.67	0.14	0.24	19.34
	9.04	2.20	0.06	0.03	3.32
<i>Poa annua</i>	13.89	0.88	0.04	0.05	4.34
	9.04	0.83	0.03	0.03	2.80
<i>Polygonum hydropiperoides</i>	5.56	0.03	0.00	0.02	0.89
	5.56	0.03	0.00	0.02	0.89

Spring	Metric				
2008	ISF	PFC	SRC	SRF	SIV
<i>Ranunculus longirostris</i>	75.00	37.64	0.51	0.30	40.48
	11.98	12.59	0.14	0.06	9.73
<i>Sparganium americanum</i>	5.56	0.17	0.01	0.02	1.18
	5.56	0.17	0.01	0.02	1.18
<i>Veronica anagallis-aquatica</i>	5.56	0.83	0.03	0.02	2.55
	5.56	0.83	0.03	0.02	2.55
2009					
<i>Lemna trisulca</i>	27.78	4.67	0.06	0.07	6.10
	10.24	3.32	0.04	0.02	2.27
Mosses	61.11	8.11	0.14	0.14	14.26
	13.38	4.00	0.07	0.03	4.41
Filamentous green algae	11.11	0.06	0.00	0.03	1.42
	7.03	0.04	0.00	0.02	0.97
<i>Batrachospermum</i>	33.33	1.25	0.02	0.08	4.97
	8.61	0.81	0.01	0.02	1.58
<i>Nostoc</i>	44.45	0.50	0.01	0.10	5.54
	11.11	0.19	0.00	0.02	1.27
<i>Callitriche heterophylla</i>	16.67	1.03	0.02	0.04	2.97
	7.45	0.81	0.01	0.02	1.50
<i>Cardamine bulbosa</i>	11.11	0.33	0.00	0.03	1.70
	7.03	0.21	0.00	0.02	1.08
<i>Elodea nuttallii</i>	38.89	9.28	0.13	0.10	11.72
	5.56	5.86	0.08	0.02	4.87
<i>Nasturtium officinale</i>	55.56	13.11	0.17	0.14	15.05
	14.06	4.24	0.05	0.03	3.63
<i>Ranunculus longirostris</i>	88.89	31.86	0.42	0.22	31.98
	7.03	11.17	0.13	0.02	7.45
<i>Sparganium americanum</i>	11.11	1.00	0.02	0.03	2.44
	7.03	0.82	0.02	0.02	1.62
<i>Veronica anagallis-aquatica</i>	11.11	1.67	0.02	0.02	1.87
	11.11	1.67	0.02	0.02	1.87
Blue 2007					
<i>Lemna trisulca</i>	38.89	10.31	0.09	0.06	7.66
	20.03	7.32	0.06	0.03	4.25
Mosses	100.00	39.89	0.53	0.28	40.44
	0.00	7.25	0.12	0.05	8.05
Filamentous green algae	77.78	7.17	0.09	0.20	14.26
	7.03	2.62	0.03	0.02	1.97
<i>Nostoc</i>	38.89	0.78	0.01	0.09	5.08
	18.09	0.37	0.00	0.04	2.37
<i>Callitriche heterophylla</i>	27.78	3.50	0.03	0.04	3.35
	18.09	2.22	0.02	0.02	2.14
<i>Cardamine bulbosa</i>	66.67	8.75	0.11	0.16	13.07
	12.17	2.46	0.03	0.02	1.98

Spring	Metric				
2007	ISF	PFC	SRC	SRF	SIV
<i>Eleocharis acicularis</i>	5.56	0.17	0.00	0.01	0.43
	5.56	0.17	0.00	0.01	0.43
<i>Elodea nuttallii</i>	5.56	0.17	0.00	0.01	0.43
	5.56	0.17	0.00	0.01	0.43
<i>Glyceria striata</i>	5.56	2.08	0.03	0.02	2.34
	5.56	2.08	0.03	0.02	2.34
<i>Nasturtium officinale</i>	11.11	1.00	0.01	0.01	1.17
	11.11	1.00	0.01	0.01	1.17
<i>Poa annua</i>	5.56	0.00	0.00	0.02	1.19
	5.56	0.00	0.00	0.02	1.19
<i>Physostegia virginiana</i>	5.56	0.83	0.01	0.01	0.74
	5.56	0.83	0.01	0.01	0.74
<i>Potamogeton illinoensis</i>	11.11	0.19	0.00	0.01	0.81
	11.11	0.19	0.00	0.01	0.81
<i>Ranunculus longirostris</i>	11.11	1.67	0.01	0.01	1.47
	11.11	1.67	0.01	0.01	1.47
<i>Rumex obtusifolius</i>	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00
<i>Sagittaria latifolia</i>	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00
<i>Sparganium americanum</i>	16.67	2.50	0.02	0.02	2.17
	16.67	2.50	0.02	0.02	2.17
<i>Veronica anagallis-aquatica</i>	16.67	3.75	0.05	0.04	4.63
	7.45	2.02	0.03	0.02	2.42
<i>Zannichellia palustris</i>	5.56	0.83	0.01	0.01	0.72
	5.56	0.83	0.01	0.01	0.72
2008					
<i>Lemna trisulca</i>	27.78	3.00	0.03	0.05	3.87
	13.38	2.90	0.02	0.03	2.08
Mosses	100.00	45.58	0.66	0.28	46.92
	0.00	6.13	0.10	0.05	7.15
Filamentous green algae	94.45	13.19	0.16	0.25	20.52
	5.56	5.20	0.06	0.03	3.19
<i>Batrachospermum</i>	11.11	0.06	0.00	0.02	1.20
	7.03	0.04	0.00	0.01	0.76
<i>Nostoc</i>	33.33	1.25	0.02	0.08	5.11
	12.17	0.78	0.01	0.03	1.82
<i>Callitriche heterophylla</i>	16.67	2.50	0.02	0.02	2.24
	16.67	2.50	0.02	0.02	2.24
<i>Cardamine bulbosa</i>	33.33	5.58	0.06	0.06	6.37
	12.17	2.38	0.03	0.02	2.26
<i>Elodea nuttallii</i>	5.56	0.17	0.00	0.01	0.47
	5.56	0.17	0.00	0.01	0.47
<i>Glyceria striata</i>	16.67	0.50	0.01	0.04	2.49
	11.39	0.34	0.00	0.03	1.75

Spring	Metric				
2008	ISF	PFC	SRC	SRF	SIV
<i>Nasturtium officinale</i>	5.56	0.17	0.00	0.01	0.47
	5.56	0.17	0.00	0.01	0.47
<i>Physostegia virginiana</i>	5.56	0.03	0.00	0.01	0.54
	5.56	0.03	0.00	0.01	0.54
<i>Potamogeton illinoensis</i>	11.11	0.19	0.00	0.02	0.88
	11.11	0.19	0.00	0.02	0.88
<i>Ranunculus longirostris</i>	22.22	1.19	0.01	0.04	2.61
	16.48	1.01	0.01	0.03	2.10
<i>Sparganium americanum</i>	16.67	2.50	0.02	0.02	2.24
	16.67	2.50	0.02	0.02	2.24
<i>Veronica anagallis-aquatica</i>	22.22	0.25	0.00	0.08	4.10
	11.11	0.19	0.00	0.04	2.12
2009					
<i>Lemna trisulca</i>	72.22	11.42	0.09	0.14	11.38
	18.09	7.93	0.05	0.03	3.42
Mosses	94.33	41.17	0.55	0.24	39.73
	5.67	9.21	0.12	0.06	8.29
Filamentous green algae	61.17	5.89	0.07	0.14	10.21
	5.57	2.67	0.02	0.01	0.98
Nostoc	55.55	1.69	0.02	0.12	7.16
	14.06	0.72	0.01	0.02	1.25
<i>Callitriche heterophylla</i>	22.22	2.75	0.02	0.05	3.34
	7.03	2.45	0.02	0.01	0.71
<i>Cardamine bulbosa</i>	55.56	6.83	0.07	0.11	8.98
	16.48	2.09	0.02	0.03	2.40
<i>Elodea nuttallii</i>	11.11	3.08	0.02	0.02	1.82
	11.11	3.08	0.02	0.02	1.82
<i>Glyceria striata</i>	11.11	1.00	0.02	0.02	2.09
	7.03	0.82	0.02	0.02	1.39
<i>Nasturtium officinale</i>	5.56	0.03	0.00	0.03	1.42
	5.56	0.03	0.00	0.03	1.42
<i>Physostegia virginiana</i>	5.56	2.08	0.02	0.01	1.67
	5.56	2.08	0.02	0.01	1.67
<i>Potamogeton illinoensis</i>	11.11	1.00	0.01	0.02	1.13
	11.11	1.00	0.01	0.02	1.13
<i>Ranunculus longirostris</i>	27.78	2.69	0.03	0.05	4.06
	13.38	1.76	0.02	0.03	2.23
<i>Sparganium americanum</i>	16.67	5.14	0.03	0.02	2.89
	16.67	5.14	0.03	0.02	2.89
<i>Veronica anagallis-aquatica</i>	16.67	3.08	0.05	0.04	4.13
	11.39	2.24	0.03	0.03	2.84
Pulltite 2007					
<i>Lemna minor</i>	5.56	0.03	0.00	0.01	0.71
	5.56	0.03	0.00	0.01	0.71
<i>Lemna trisulca</i>	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00

Spring	Metric				
2009	ISF	PFC	SRC	SRF	SIV
Mosses	88.89	54.08	0.58	0.36	46.95
	11.11	11.92	0.12	0.07	9.03
Filamentous green algae	72.22	13.03	0.14	0.29	21.62
	15.91	5.00	0.06	0.07	5.85
Nostoc	11.11	0.33	0.00	0.03	1.58
	11.11	0.33	0.00	0.03	1.58
<i>Callitriche heterophylla</i>	5.56	0.03	0.00	0.01	0.71
	5.56	0.03	0.00	0.01	0.71
<i>Cardamine bulbosa</i>	0.00	0.83	0.01	0.00	0.45
	0.00	0.83	0.01	0.00	0.45
<i>Elodea nuttallii</i>	11.11	11.53	0.13	0.04	8.13
	11.11	9.26	0.10	0.04	6.87
<i>Nasturtium officinale</i>	16.67	2.50	0.03	0.06	4.39
	7.45	1.12	0.01	0.03	1.97
<i>Polygonum hydropiperoides</i>	27.78	4.94	0.06	0.08	6.93
	15.91	2.98	0.03	0.04	3.61
<i>Ranunculus longirostris</i>	11.11	1.67	0.02	0.04	2.76
	11.11	1.67	0.02	0.04	2.76
<i>Sparganium americanum</i>	16.67	2.50	0.03	0.06	4.14
	16.67	2.50	0.03	0.06	4.14
<i>Veronica anagallis-aquatica</i>	5.56	0.83	0.01	0.02	1.62
	5.56	0.83	0.01	0.02	1.62
2008					
Mosses	88.89	44.17	0.52	0.21	36.68
	11.11	7.94	0.11	0.03	6.71
<i>Batrachospermum</i>	50.00	3.75	0.04	0.11	7.32
	14.27	1.74	0.02	0.02	2.13
Nostoc	77.78	4.58	0.05	0.18	11.53
	16.48	1.72	0.02	0.04	2.51
Filamentous green algae	77.78	7.25	0.08	0.17	12.92
	16.48	1.77	0.02	0.04	2.87
<i>Callitriche heterophylla</i>	5.56	0.83	0.01	0.01	1.00
	5.56	0.83	0.01	0.01	1.00
<i>Elodea nuttallii</i>	11.11	6.81	0.08	0.04	5.89
	11.11	6.81	0.08	0.04	5.89
<i>Nasturtium officinale</i>	27.78	6.58	0.07	0.08	7.20
	13.38	3.53	0.04	0.04	3.90
<i>Polygonum hydropiperoides</i>	44.44	6.44	0.07	0.09	8.28
	18.59	3.59	0.04	0.03	3.46
<i>Ranunculus longirostris</i>	5.56	0.83	0.01	0.02	1.51
	5.56	0.83	0.01	0.02	1.51
<i>Sparganium americanum</i>	11.11	1.67	0.02	0.04	3.02
	11.11	1.67	0.02	0.04	3.02
<i>Veronica anagallis-aquatica</i>	22.22	5.17	0.05	0.04	4.66
	16.48	4.25	0.04	0.03	3.59

Spring	Metric				
2009	ISF	PFC	SRC	SRF	SIV
Mosses	88.88	43.36	0.61	0.26	43.75
	11.12	10.69	0.14	0.03	8.44
Filamentous green algae	66.67	6.03	0.09	0.18	13.77
	17.21	2.38	0.04	0.04	3.65
<i>Batrachospermum</i>	22.22	2.33	0.05	0.07	5.65
	7.03	2.04	0.04	0.02	2.80
Nostoc	72.22	1.33	0.02	0.20	11.25
	15.91	0.40	0.01	0.04	2.39
<i>Callitriche heterophylla</i>	5.55	0.17	0.00	0.02	1.21
	5.55	0.17	0.00	0.02	1.21
<i>Cardamine bulbosa</i>	5.56	0.83	0.01	0.02	1.37
	5.56	0.83	0.01	0.02	1.37
<i>Elodea nuttallii</i>	11.11	3.64	0.07	0.04	5.71
	11.11	3.64	0.07	0.04	5.71
<i>Nasturtium officinale</i>	11.11	0.86	0.01	0.03	2.23
	7.03	0.83	0.01	0.02	1.41
<i>Polygonum hydropiperoides</i>	38.89	5.47	0.07	0.11	9.09
	13.38	3.54	0.05	0.03	3.62
<i>Ranunculus longirostris</i>	5.56	0.03	0.00	0.02	1.07
	5.56	0.03	0.00	0.02	1.07
<i>Sparganium americanum</i>	5.56	2.25	0.04	0.02	3.28
	5.56	2.25	0.04	0.02	3.28
<i>Veronica anagallis-aquatica</i>	5.56	0.83	0.02	0.02	1.62
	5.56	0.83	0.02	0.02	1.62
Round 2007					
<i>Lemna minor</i>	5.56	0.03	0.00	0.01	0.72
	5.56	0.03	0.00	0.01	0.72
<i>Lemna trisulca</i>	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00
Mosses	44.44	5.14	0.06	0.09	7.66
	7.03	2.65	0.03	0.01	1.56
Filamentous green algae	61.11	15.75	0.14	0.13	13.50
	13.38	6.25	0.05	0.03	3.43
Nostoc	22.22	1.39	0.02	0.04	3.06
	11.11	0.95	0.01	0.02	1.49
<i>Callitriche heterophylla</i>	16.67	0.06	0.00	0.04	2.07
	7.45	0.04	0.00	0.02	0.93
<i>Ceratophyllum demersum</i>	22.22	3.64	0.06	0.05	5.80
	16.48	3.44	0.06	0.04	5.02
<i>Elodea nuttallii</i>	50.00	6.75	0.07	0.11	9.08
	14.27	2.18	0.02	0.03	1.63
<i>Myriophyllum heterophyllum</i>	55.56	17.64	0.17	0.12	14.62
	14.06	8.18	0.09	0.03	5.92
<i>Nasturtium officinale</i>	44.44	7.00	0.07	0.10	8.36
	7.03	3.12	0.02	0.01	1.38

Spring	Metric				
2007	ISF	PFC	SRC	SRF	SIV
<i>Poa annua</i>	22.22	1.20	0.02	0.05	3.18
	16.48	0.84	0.01	0.04	2.31
<i>Potamogeton illinoensis</i>	38.89	15.83	0.20	0.08	14.23
	15.91	7.82	0.11	0.03	6.09
<i>Sparganium americanum</i>	66.67	18.57	0.17	0.14	15.77
	14.91	3.85	0.05	0.03	1.31
<i>Veronica anagallis-aquatica</i>	11.11	1.67	0.01	0.02	1.94
	7.03	1.05	0.01	0.02	1.23
2008					
Mosses	44.45	9.61	0.10	0.10	9.78
	11.11	5.76	0.05	0.03	3.62
Filamentous green algae	66.67	8.44	0.10	0.16	13.33
	12.17	4.65	0.05	0.04	3.08
<i>Batrachospermum</i>	38.89	0.97	0.02	0.08	4.70
	15.91	0.46	0.01	0.02	1.55
<i>Nostoc</i>	27.78	1.14	0.01	0.06	3.50
	18.09	0.98	0.01	0.04	2.27
<i>Cardamine bulbosa</i>	11.11	0.83	0.05	0.02	3.59
	7.03	0.83	0.05	0.02	3.11
<i>Callitriche heterophylla</i>	0.00	0.03	0.00	0.00	0.02
	0.00	0.03	0.00	0.00	0.02
<i>Ceratophyllum demersum</i>	11.11	0.83	0.05	0.02	3.59
	7.03	0.83	0.05	0.02	3.11
<i>Elodea nuttallii</i>	27.78	1.25	0.05	0.06	5.82
	10.24	0.80	0.05	0.03	3.80
<i>Myriophyllum heterophyllum</i>	44.44	19.36	0.22	0.11	16.44
	7.03	9.73	0.10	0.03	6.28
<i>Nasturtium officinale</i>	61.11	8.50	0.11	0.13	11.81
	18.09	2.50	0.04	0.03	3.20
<i>Poa annua</i>	33.33	0.61	0.01	0.06	3.65
	12.17	0.31	0.01	0.02	1.18
<i>Potamogeton illinoensis</i>	22.22	14.44	0.18	0.04	10.95
	16.48	7.76	0.11	0.03	6.42
<i>Sparganium americanum</i>	44.44	6.92	0.07	0.11	9.26
	14.06	3.73	0.03	0.04	3.25
<i>Veronica anagallis-aquatica</i>	11.11	2.92	0.03	0.02	2.62
	7.02	2.08	0.02	0.01	1.72
<i>Polygonum hydropiperoides</i>	5.56	0.03	0.00	0.02	0.91
	5.56	0.03	0.00	0.02	0.91
2009					
Mosses	38.89	6.19	0.08	0.09	8.79
	13.38	4.04	0.05	0.03	3.99
Filamentous green algae	61.11	3.69	0.04	0.16	10.03
	18.09	1.48	0.02	0.04	3.07
<i>Batrachospermum</i>	22.22	1.19	0.03	0.05	4.07
	11.11	0.97	0.02	0.03	2.50

Spring	Metric				
2009	ISF	PFC	SRC	SRF	SIV
<i>Nostoc</i>	5.56	0.17	0.00	0.01	0.66
	5.56	0.17	0.00	0.01	0.66
<i>Callitriche heterophylla</i>	5.56	0.03	0.00	0.01	0.57
	5.56	0.03	0.00	0.01	0.57
<i>Ceratophyllum demersum</i>	16.67	6.83	0.07	0.04	5.69
	7.45	4.76	0.05	0.02	3.12
<i>Elodea nuttallii</i>	38.89	5.75	0.08	0.09	8.43
	13.38	2.61	0.03	0.03	2.89
<i>Ludwigia palustris</i>	5.56	0.83	0.01	0.02	1.30
	5.56	0.83	0.01	0.02	1.30
<i>Myriophyllum heterophyllum</i>	55.56	20.58	0.22	0.15	18.58
	18.59	7.77	0.08	0.05	6.39
<i>Nasturtium officinale</i>	11.11	1.67	0.02	0.03	2.28
	11.11	1.67	0.02	0.03	2.28
<i>Poa annua</i>	22.22	1.33	0.02	0.05	3.38
	11.11	0.95	0.01	0.02	1.73
<i>Potamogeton illinoensis</i>	27.78	13.33	0.19	0.08	13.46
	10.24	5.59	0.08	0.03	5.28
<i>Ranunculus longirostris</i>	5.56	0.17	0.00	0.01	0.90
	5.56	0.17	0.00	0.01	0.90
<i>Sparganium americanum</i>	61.11	19.08	0.21	0.16	18.15
	13.38	5.28	0.05	0.03	4.24
<i>Veronica anagallis-aquatica</i>	22.22	1.06	0.02	0.05	3.69
	14.06	0.84	0.02	0.03	2.52
Welch 2007					
Mosses	55.56	34.17	0.52	0.35	43.07
	29.40	19.97	0.29	0.22	25.23
Filamentous green algae	22.22	0.39	0.01	0.13	6.86
	11.11	0.31	0.01	0.07	3.68
<i>Nostoc</i>	22.22	0.39	0.01	0.10	5.08
	22.22	0.39	0.01	0.10	5.08
<i>Callitriche heterophylla</i>	16.67	1.67	0.02	0.11	6.70
	16.67	1.67	0.02	0.11	6.70
<i>Myriophyllum heterophyllum</i>	44.44	26.67	0.38	0.27	32.45
	29.40	20.73	0.28	0.20	24.25
<i>Sparganium americanum</i>	11.11	4.17	0.07	0.05	5.82
	11.11	4.17	0.07	0.05	5.82
2008					
Mosses	55.56	26.67	0.38	0.25	31.32
	29.40	15.64	0.24	0.14	19.31
<i>Batrachospermum</i>	11.11	1.67	0.03	0.06	4.06
	11.11	1.67	0.03	0.06	4.06
<i>Filamentous green algae</i>	88.89	14.50	0.20	0.37	28.50
	11.11	4.77	0.05	0.02	3.62

Spring	Metric				
2008	ISF	PFC	SRC	SRF	SIV
<i>Myriophyllum heterophyllum</i>	27.78	13.19	0.18	0.11	14.63
	14.70	6.62	0.09	0.06	7.62
<i>Nasturtium officinale</i>	27.78	7.92	0.12	0.11	11.59
	14.70	5.61	0.10	0.06	7.50
<i>Sparganium americanum</i>	11.11	4.17	0.05	0.04	4.49
	11.11	4.17	0.05	0.04	4.49
<i>Veronica anagallis-aquatica</i>	16.67	2.50	0.04	0.07	5.42
	16.67	2.50	0.04	0.07	5.42
2009					
Mosses	88.89	36.67	0.54	0.35	44.41
	11.11	5.83	0.11	0.08	9.13
Filamentous green algae	66.67	9.28	0.12	0.24	18.33
	19.25	5.06	0.06	0.06	5.56
<i>Batrachospermum</i>	33.33	3.67	0.05	0.11	8.09
	19.25	1.86	0.03	0.06	4.05
<i>Myriophyllum heterophyllum</i>	33.33	12.78	0.18	0.10	14.31
	19.25	6.46	0.10	0.05	7.35
<i>Nasturtium officinale</i>	33.33	2.33	0.03	0.10	6.60
	19.25	1.86	0.02	0.05	3.49
<i>Sparganium americanum</i>	11.11	4.17	0.07	0.05	5.82
	11.11	4.17	0.07	0.05	5.82
<i>Veronica anagallis-aquatica</i>	11.11	0.06	0.00	0.05	2.43
	11.11	0.06	0.00	0.05	2.43

Appendix B.

Table B-2. Water quality data from six large springs at OZAR, 2007-2009.

Spring	Parameter	Statistic	2007	2008	2009
Alley	Temperature	Mean	13.85	13.64	13.56
		Standard Error	0.01	0.004	0.003
		Range	13.8-13.96	13.62-13.7	13.52-13.64
		N	70	31	116
	Dissolved Oxygen	Mean	8.40	9.63	9.32
		Standard Error	0.07	0.02	0.02
		Range	7.18-9.36	9.52-9.81	8.91-9.82
		N	70	31	116
	Specific Conductance	Mean			
			249.90	293.68	286.63
		Standard Error	4.93	0.09	0.16
		Range	162.00-292.00	292.00-294.00	284.00-290.00
Big	pH	N	70	31	116
		Mean	7.52	7.43	7.33
		Standard Error	0.002	0.002	0.002
		Range	7.45-7.55	7.42-7.45	7.29-7.38
	Turbidity	N	70	31	116
		Mean	3.09	0.60	0.12
		Standard Error	0.01	0.003	0.006
		Range	2.9-3.4	0.6-0.7	0-0.4
	Temperature	N	70	31	116
		Mean	14.37	13.95	14.30
		Standard Error	0.01	0.01	0.01
		Range	14.32-14.54	13.92-14.07	14.25-14.41
Blue	Dissolved Oxygen	N	77	40	26
		Mean	10.35	9.22	8.58
		Standard Error	0.04	0.02	0.04
		Range	9.5-11.28	9.01-9.64	8.21-8.9
	Specific Conductance	N	77	40	26
		Mean			
			349.74	318.95	342.65
		Standard Error	0.93	1.29	0.09
	pH	Range	331-358	302-330	342-343
		N	77	40	26
		Mean	7.53	7.34	7.36
		Standard Error	0.002	0.001	0.002
Turbidity	Range	7.51-7.57	7.33-7.35	7.34-7.37	
	N	77	40	26	
	Mean	2.64	1.60	0.42	
	Standard Error	0.04	0.07	0.12	
Temperature	Range	2.4-4.8	1.2-3.7	0-2.8	
	N	77	40	26	
	Mean	13.71	13.38	13.75	
	Standard Error	0.003	0.005	0.002	
Dissolved Oxygen	Range	13.7-13.75	13.36-13.45	13.74-13.78	
	N	42	24	48	
	Mean	8.89	9.48	10.05	

Spring	Parameter	Statistic	2007	2008	2009
		Standard Error	0.03	0.06	0.04
		Range	8.49-9.51	8.91-10.03	9.59-10.47
		N	42	24	48
	Specific Conductance	Mean	127.93	233.54	227.85
		Standard Error	5.97	4.99	4.88
		Range	88-279	197-266	175-279
		N	42	24	48
	pH	Mean	7.60	7.54	7.43
		Standard Error	0.001	0.002	0.004
		Range	7.58-7.61	7.53-7.56	7.36-7.54
		N	42	24	48
	Turbidity	Mean	5.08	0.2	0.08
		Standard Error	0.01	0.03	0.01
		Range	5-5.4	0-0.6	0-0.3
		N	42	24	48
Pulltite	Temperature	Mean	14.03	13.76	13.80
		Standard Error	0.001	0.002	0.0005
		Range	14.01-14.06	13.76-13.85	13.79-13.8
		N	98	49	47
	Dissolved Oxygen	Mean	8.42	8.23	8.25
		Standard Error	0.006	0.02	0.003
		Range	8.36-8.75	8.01-8.69	8.23-8.34
		N	98	49	47
	Specific Conductance	Mean	295.84	277.71	288.79
		Standard Error	0.14	0.27	0.09
		Range	293-298	266-279	288-290
		N	98	49	47
	pH	Mean	7.38	7.36	7.27
		Standard Error	0.001	0.001	0.001
		Range	7.33-7.39	7.34-7.4	7.27-7.31
	N		98	49	47
	Turbidity	Mean	5.77	0.92	0.57
		Standard Error	0.01	0.02	0.008108
		Range	5.7-5.9	0.7-1.9	0.4-0.7
		N	98	49	47
Round	Temperature	Mean	13.82	13.60	13.67
		Standard Error	0.02	0.02	0.01
		Range	13.71-14.1	13.5-13.83	13.59-13.91
		N	69	25	184
	Dissolved Oxygen	Mean	9.06	9.27	9.11
		Standard Error	0.04	0.07	0.02
		Range	8.64-9.74	8.95-9.89	8.85-9.65
		N	69	25	184
	Specific Conductance	Mean	202.93	311.04	306.96
		Standard Error	2.17	0.50	0.98
		Range	167-226	307-315	267-324
		N	69	25	184
	pH	Mean	7.44	7.41	7.27
		Standard Error	0.002	0.003	0.001
		Range	7.4-7.48	7.39-7.43	7.25-7.38

Spring	Parameter	Statistic	2007	2008	2009
		N	69	25	184
	Turbidity	Mean	5.64	1.18	0.275
		Standard Error	0.008	0.20	0.02
		Range	5.6-5.9	0.7-5.9	0-1.8
		N	69	25	184
Welch	Temperature	Mean	13.67	13.50667	13.59333
		Standard Error	0.01	0.003	0.05
		Range	13.66-13.68	13.5-13.51	13.52-13.7
		N	3	3	3
	Dissolved Oxygen	Mean	10.43	--	11.13667
		Standard Error	0.18	--	0.21
		Range	10.09-10.72	--	10.73-11.44
		N	3	--	3
	Specific Conductance	Mean	324.67	314	320.33
		Standard Error	3.33	0	0.33
		Range	318-328	314-314	320-321
		N	3	3	3
	pH	Mean	7.16	7.37	7.42
		Standard Error	0.03	0.01	0.04
		Range	7.11-7.2	7.35-7.38	7.35-7.47
		N	3	3	3
	Turbidity	Mean	5	0.2	0.87
		Standard Error	0.1	0.12	0.43
		Range	4.8-5.1	0-0.4	0-1.3
		N	3	3	3

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