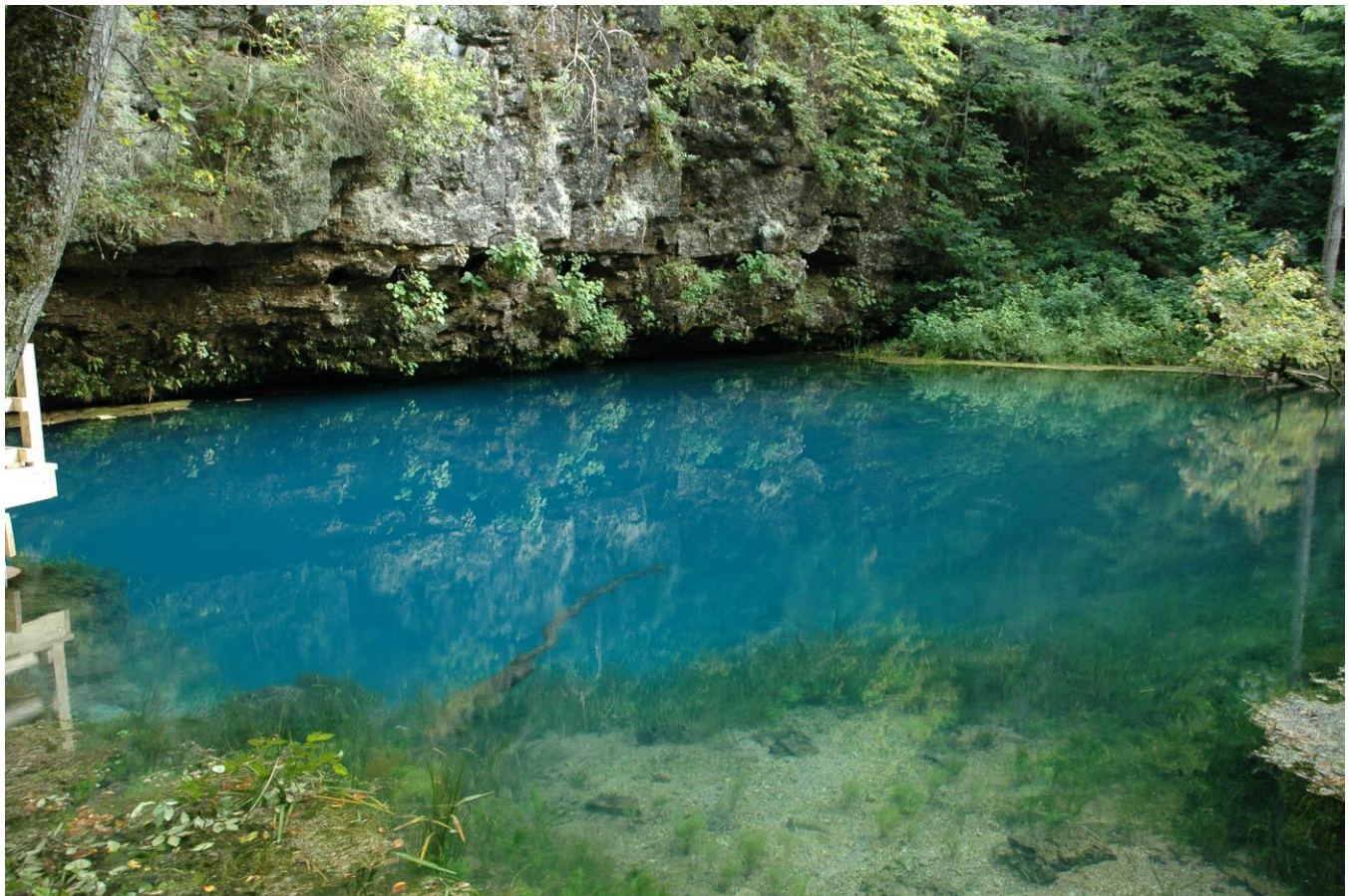




Aquatic Vegetation Monitoring in Springs at Ozark National Scenic Riverways, 2007-2015

Natural Resource Data Series NPS/OZAR/NRDS—2016/1044





ON THIS PAGE

Photograph of Heartland Network researchers surveying aquatic vegetation at Pulltite Spring, Ozark National Scenic Riverways. Photograph courtesy of the National Park Service, Heartland Inventory & Monitoring Network.

ON THE COVER

Photograph of Blue Spring, Ozark National Scenic Riverways.
Photograph courtesy of the National Park Service, Heartland Inventory & Monitoring Network.

Aquatic Vegetation Monitoring in Springs at Ozark National Scenic Riverways, 2007-2015

Natural Resource Data Series NPS/OZAR/NRDS—2016/1044

David E. Bowles and Hope R. Dodd

National Park Service
Heartland Inventory and Monitoring Network
Wilson's Creek National Battlefield
6424 West Farm Road 182
Republic, Missouri, 65738

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U.S. Department of the Interior
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Fort Collins, Colorado

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The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal, editorial review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Abstract

We studied the aquatic vegetation communities of seven large springs located at Ozark National Scenic Riverways, Missouri from 2007–2015. Our data provides a baseline for assessing the impacts of anthropogenic and natural disturbances on the ecological integrity of springs. Vegetation was assessed quantitatively along sample cells located on multiple transects in each spring. The springs contain 69 distinct taxa, collectively. Substantial overlap of species occurred among springs, including 6 families, 6 genera and 6 species of algae, and 9 families, 12 genera and 19 species of mosses and liverworts. Among angiosperms, we report 10 families, 13 genera, and 20 species of monocots, and 16 families, 23 genera and 24 species of dicots. Alley Spring had the most diverse plant community while Welch and Phillips springs had the lowest diversity. Individual sample cells typically contained four to six taxa, although Welch and Phillips Spring generally had no more than three taxa represented on average. Alley spring had the highest taxa richness (mean=5.38 taxa). Effective numbers of species were generally consistent among years for all springs. Among all the springs, taxa did not occur in equal abundance in the respective communities. Exotic species are not major contributors to the vegetation communities of the seven springs assessed in this study.

Acknowledgments

We thank Tyler Cribbs, Jan Hinsey, Victoria Grant, Mike Gossett, and Myranda Clark for providing field assistance on multiple occasions. Other people who provided field assistance included Catherine Ciak, Ryan Green, Beth Bailey, Kevin Murray, Melanie Weber, Joe Chilton, Allison Keefe, Kristen Kohlhepp, Robin Graham, Mike DeBacker, Zach Morris, Chris Morris, and Josh DeLay.

Introduction

Mosses, algae, and higher plants are particularly important structural and biological constituents of springs and aquatic systems in general (Bowles et al. 2008, Bowles and Dodd 2015), and they often have complex relationships with some fish and aquatic invertebrates. Aquatic vegetation communities in spring ecosystems are vulnerable to a broad variety of anthropogenic disturbances such as water pollution, introduction of invasive species, and physical damage. Aquatic vegetation surveys are important to researchers and managers to establish inventories and aid in the diagnosis of ecosystem disturbances. Documenting the occurrences and distributions of flora in springs provides a baseline for assessing the potential for, or extent of, a variety of both anthropogenic and natural disturbances and is an integral step toward their conservation and understanding their role in ecosystem function.

The extensive dolomitic karst topography in the area surrounding Ozark National Scenic Riverways (OZAR), Missouri, is conducive to the formation of springs (Mugel et al. 2009). Springs at OZAR are highly vulnerable to biological and chemical degradation and may represent the ultimate challenge in water quality protection. We began a spring monitoring program in 2007 to provide a baseline for assessing the ecological integrity of springs at OZAR, including the aquatic vegetation community (Bowles et al. 2008). Bowles et al. (2011) reported on aquatic vegetation, invertebrate, and fish monitoring data collected from 2007 to 2009, and Bowles and Dodd (2015) reported on aquatic vegetation data collected from 2007–2012, and included a list of the taxa present in the springs. This report provides an analysis of plant community diversity from 2007–2015.

Methods

Methods used in this study follow Bowles et al. (2008). Aquatic vegetation was assessed annually at six large ($> 0.28 \text{ m}^3/\text{sec}$) springs located at Ozark National Scenic Riverways, Missouri (Fig. 1), during late July-early August from 2007 to 2015. Phillips Spring was sampled from 2011 to 2015. At each spring, the sampling reach was divided into 11 equally spaced transects perpendicular to flow with three sample cells (1 m^2) per transect. The one exception was Welch Spring, where only three transects ($N=9$) were established due to its short spring run (36m). Aquatic vegetation was sampled semi-quantitatively at odd numbered transects (six transects, $N = 18$; $N = 9$ at Welch Spring) using a PVC sampling frame (1 m^2) and view bucket to observe vegetation. The sampling frame was divided into quadrats to facilitate assessing vegetation abundance. Foliar cover for each plant species found in each sample cell was recorded using a modified Daubenmire scale: 1 = 0–0.99%, 2 = 1–5%, 3 = 5–25%, 4 = 25–50%, 5 = 50–75%, 6 = 75–95%, 7 = 95–100% (Daubenmire 1959; Bowles et al. 2008). Data collected from all sample cells were summarized by taxa for the area sampled. Mean values along with a measure of variability (± 1 standard error of the mean) were calculated for the community. Identification keys used included Redfearn (1972), Godfrey and Wooten (1979, 1981), Flora of North America North of Mexico (1993+), and Yatskievych (1999, 2006, 2013). A list of species recorded from each spring can be found in Bowles and Dodd (2015).

Foliar cover estimates for each species were used to determine measures of species diversity (McCune et al. 2002). Foliar cover data were analyzed using the midpoints of the respective cover classes and were analyzed under two broad categories: 1) diversity, and 2) individual species frequency. Diversity analyses included taxa richness, Shannon's diversity index (Shannon 1948), and Simpson's diversity index (Simpson 1949), which were subsequently expressed as effective number of species (S , H_e , D_e) (Hill 1973; Joust 2006; Bowles et al. 2008). 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 taxa richness, Shannon's diversity index and Simpson's diversity index would all be equal (Washington 1984). The advantage of converting Shannon's diversity index and Simpson's diversity index to effective number of species is that it makes their values linear thus allowing for direct comparison.

Metrics calculated for individual species included individual species frequency (ISF), percent foliar cover (PFC), and species importance value (SIV). Species importance values are a measure of the relative dominance of species in a spring community with larger importance values indicating the more dominant species. We also calculated the ratio of exotic individual species frequency to total individual species frequency, and the ratio of percent foliar cover of exotic species to percent foliar cover of all species. This latter metric serves as a measure of the relative dominance of non-native species and thus serves as means of assessing community disturbance.

Water quality and habitat data were collected in conjunction with vegetation samples (see Bowles *et al.* 2008, 2011), but those data are not presented here because they do not allow additional insight into vegetation community structure at this time. Those data will be presented later in a more exhaustive analysis.

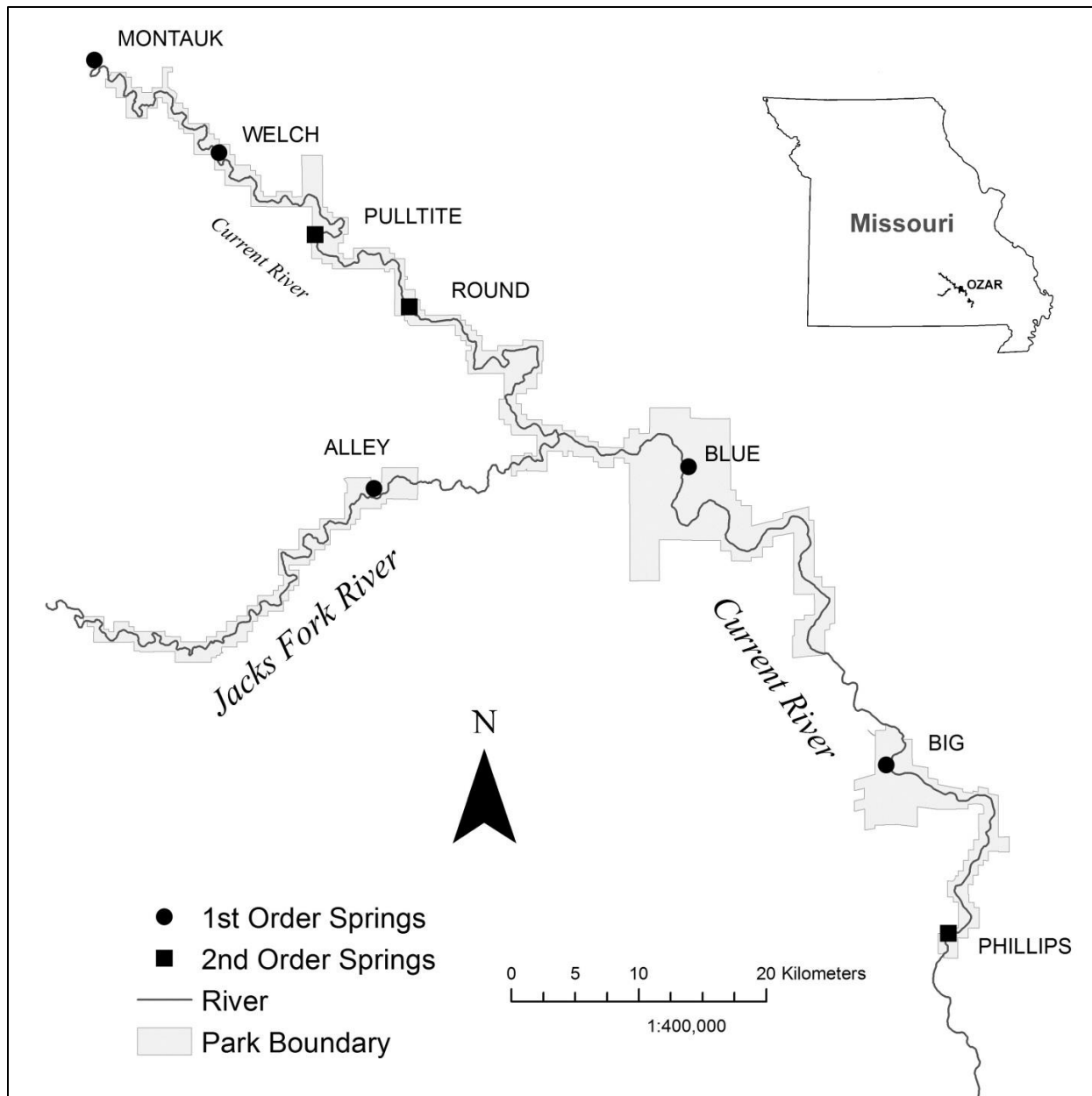


Figure 1. Map showing the locations of large springs at Ozark National Scenic Riverways, Missouri. Montauk Spring is outside of the park boundary and was not included in this study.

Results

The data reported here are similar to those reported by Bowles and Dodd (2015) with the exception of more years being reported. We found 69 distinct taxa with substantial overlap of species occurrences among springs, including 6 families, 6 genera and 6 species of algae, and 9 families, 12 genera and 19 species of mosses and liverworts (Bowles and Dodd 2015). Among angiosperms, we report 10 families, 13 genera, and 20 species of monocots, and 16 families, 23 genera and 24 species of dicots.

Individual sample cells typically contained four to six taxa, although Welch Spring generally had only two to three taxa represented (Figs. 2-8). Effective numbers of species were generally consistent among years for each spring (Figs 2A-8A), but the various species did not occur in equal abundance in the community within or among sample years (Figs 2B-8B). Taxa richness was slightly higher than Simpson's diversity index effective number (D_e) and Shannon's diversity index effective number (H_e) for all springs among all years (Figs. 2A-8A). Alley Spring had the highest mean taxa richness across years among individual sampling cells (5.39) while Welch and Phillips springs had the lowest taxa richness (2.46 and 2.44, respectively). Mean H_e and D_e across years in individual sampling cells was also greatest at Alley Spring (3.72 and 3.34, respectively) and was least at Welch Spring (1.81 and 1.68, respectively).

Alley Spring had 21 taxa represented among sampling cells with mosses, *Cardamine bulbosa* and *Nasturtium officinale* having the greatest PFC and SIV (Fig. 9). Nineteen taxa were represented in cells at Big Spring where *Ranunculus longirostris* had the greatest ISF, PFC and SIV (Fig. 10). Blue and Pulltite springs had 21 and 16 taxa represented, respectively, but mosses were dominant in both systems (Figs. 11 and 12). Round Spring had the greatest number of total taxa represented with 22, and several taxa frequently co-occurred (Fig. 13). However, *Myriophyllum heterophyllum*, *Potamogeton illinoensis*, and *Sparganium americanum* had the highest PFC and SIV. Welch and Phillips springs had the least taxa represented (13 and 14, respectively) (Figs. 14 and 15). At Phillips Spring, mosses and *Nostoc* sp. were most frequently encountered as well as having the greatest PFC and importance values. At Welch Spring, mosses and filamentous green algae were most frequently encountered, although mosses and *Myriophyllum heterophyllum* had the greatest coverage and importance values (Fig. 15). Mosses were abundant in all of the springs.

Exotic species were not major contributors to the vegetation communities of the respective springs and those that were present occurred infrequently and typically had low foliar coverage of less than 30% (Figs. 2C-8C), although that value was exceeded in some years. Watercress, *Nasturtium officinale*, was the dominant exotic plant in all springs.

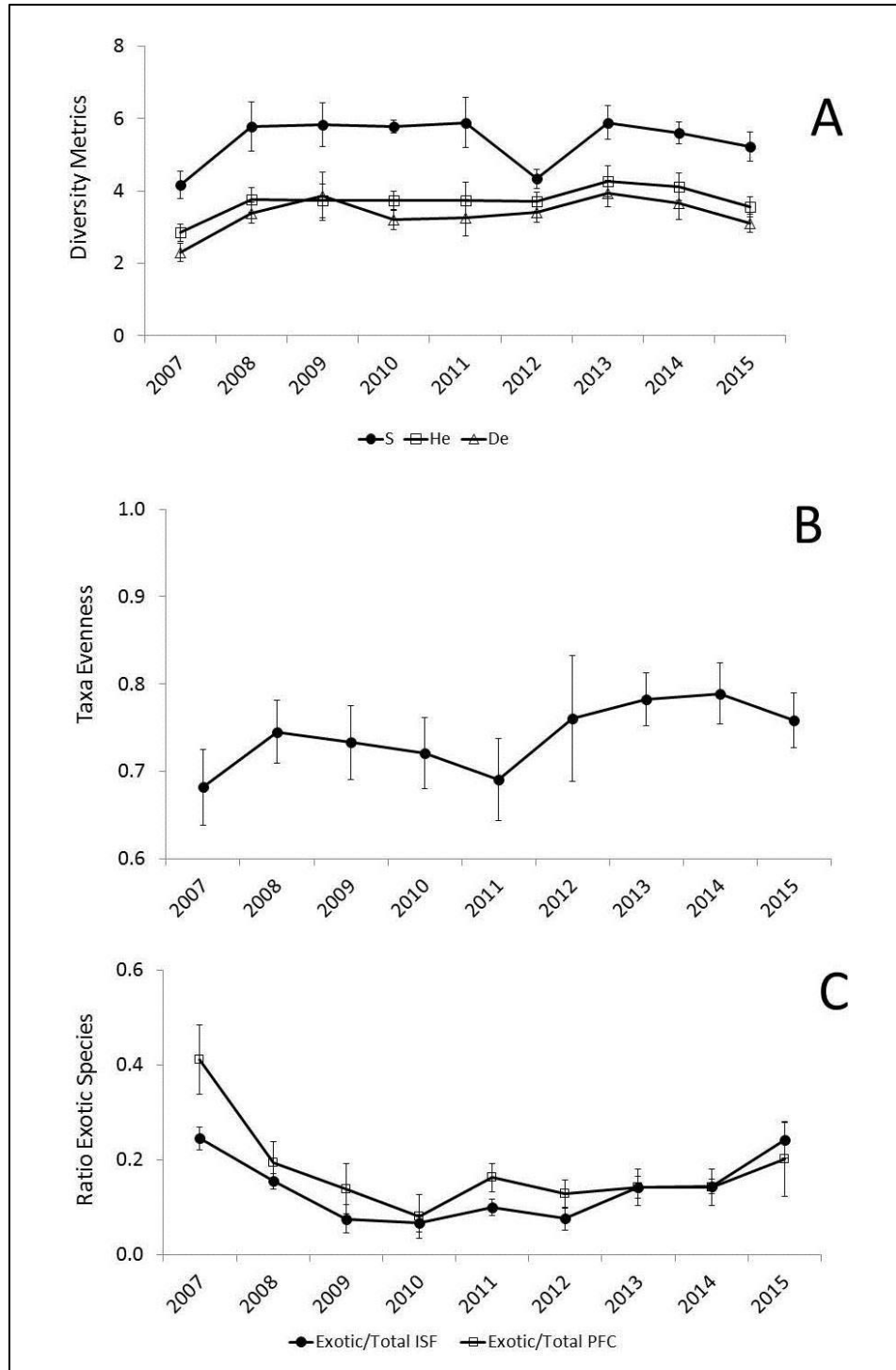


Figure 2. Diversity measures for aquatic vegetation occurring in Alley Spring, Ozark National Scenic Riverways, Missouri. Values are derived from 1 m² replicates. A. Mean and standard error (n=6) of effective numbers of species for S = taxa richness, He and De = effective number of species for Shannon's Diversity Index and Simpson's Diversity Index. B. Taxa evenness. C. Exotic/total individual species frequency and exotic/total percent foliar cover.

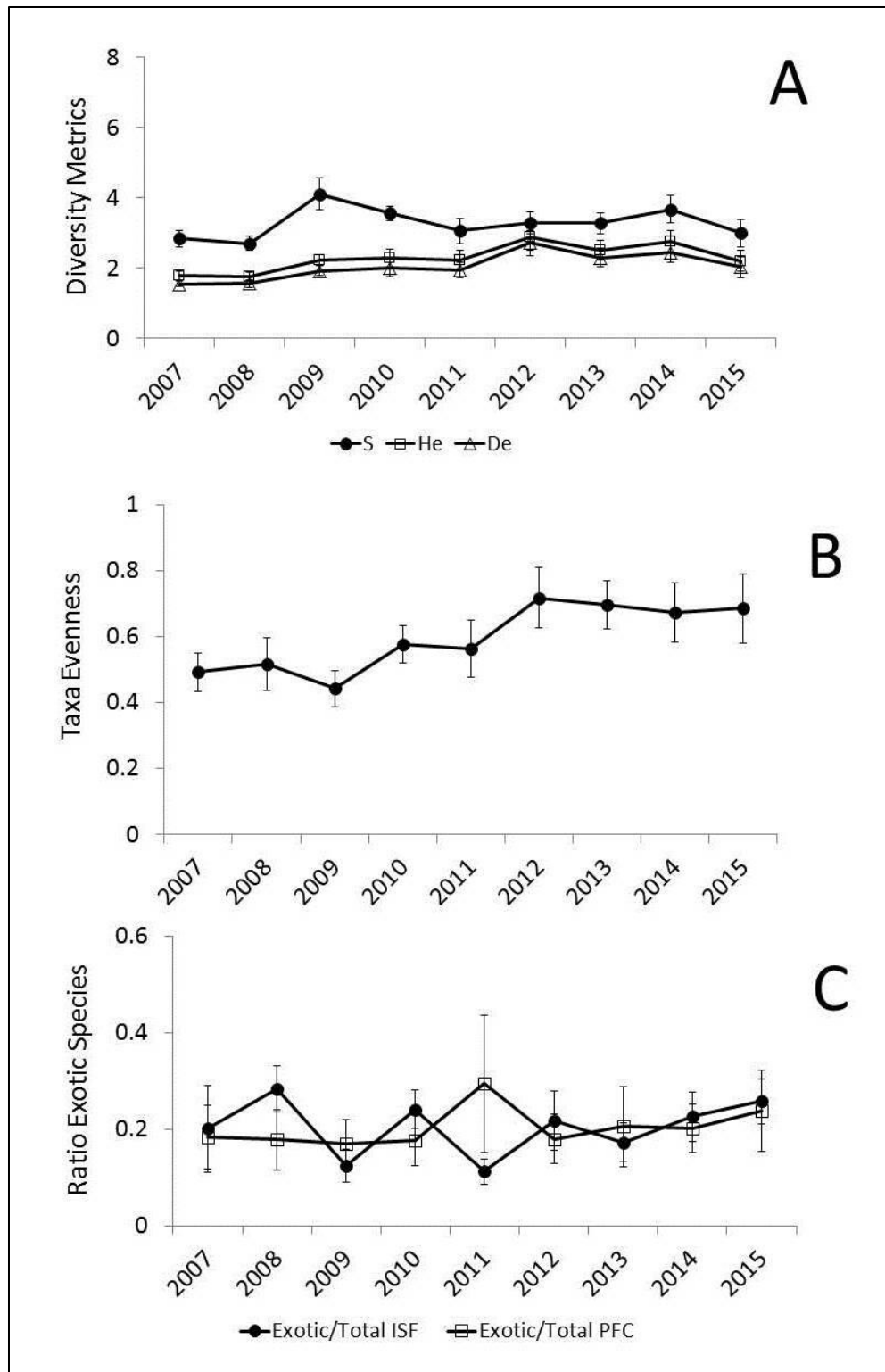


Figure 3. Diversity measures for aquatic vegetation occurring in Big Spring, Ozark National Scenic Riverways, Missouri. Values are derived from 1 m² replicates. A. Mean and standard error (n=6) of effective numbers of species for S = taxa richness, He and De = effective number of species for Shannon's Diversity Index and Simpson's Diversity Index. B. Taxa evenness. C. Exotic/total individual species frequency and exotic/total percent foliar cover.

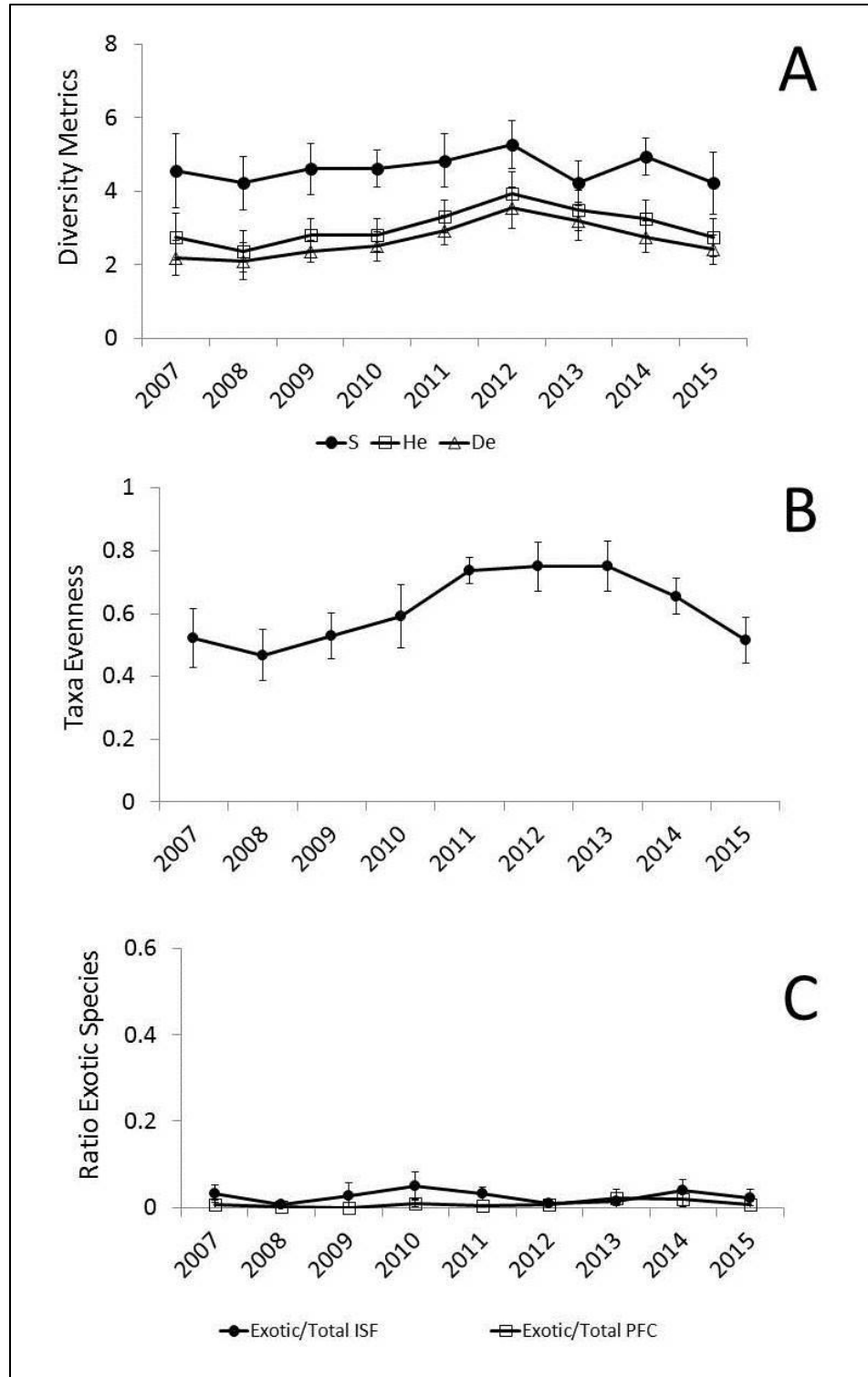


Figure 4. Diversity measures for aquatic vegetation occurring in Blue Spring, Ozark National Scenic Riverways, Missouri. Values are derived from 1 m² replicates. A. Mean and standard error (n=6) of effective numbers of species for S = taxa richness, He and De = effective number of species for Shannon's Diversity Index and Simpson's Diversity Index. B. Taxa evenness. C. Exotic/total individual species frequency and exotic/total percent foliar cover.

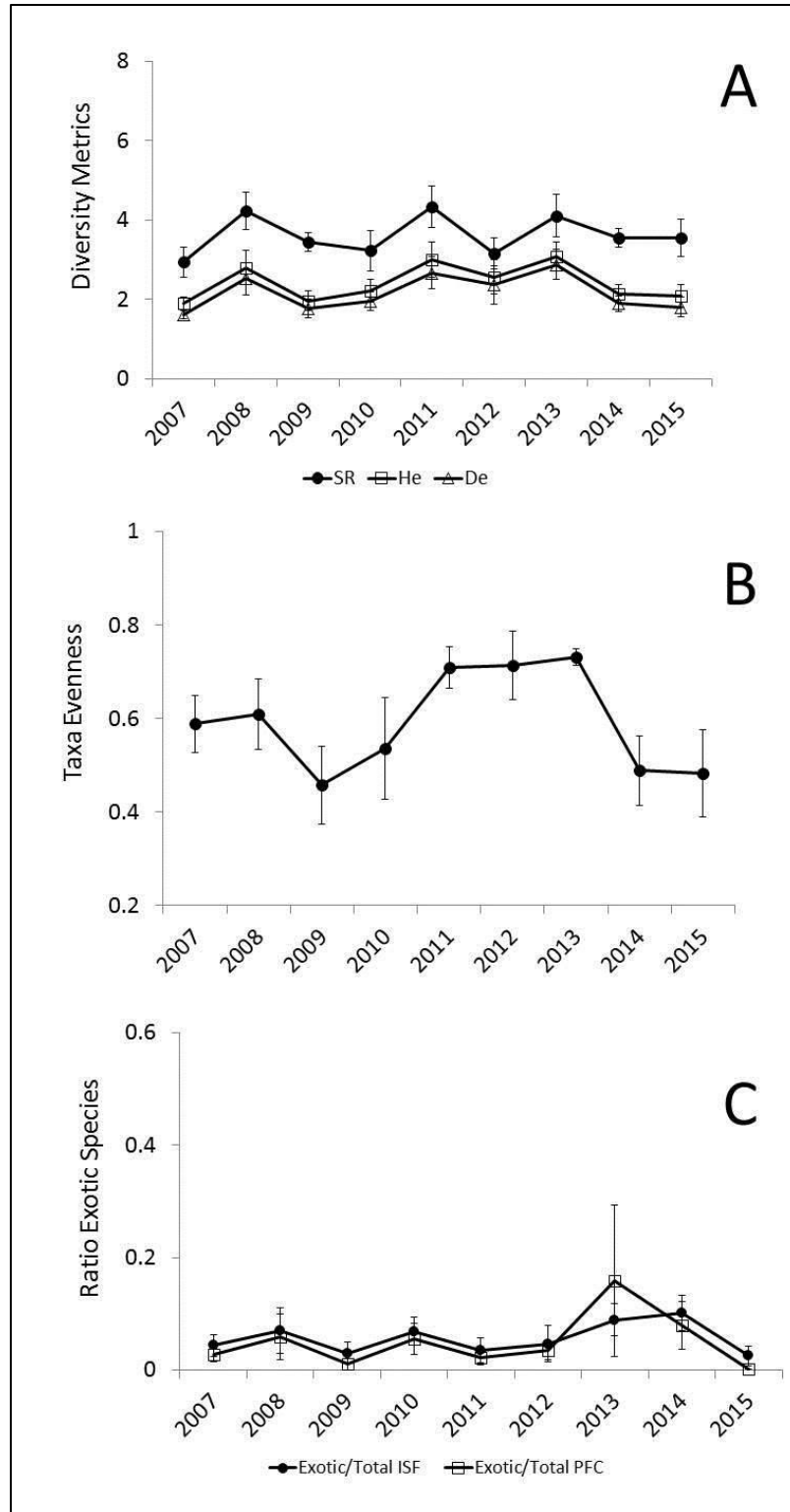


Figure 5. Diversity measures for aquatic vegetation occurring in Pulltite Spring, Ozark National Scenic Riverways, Missouri. Values are derived from 1m² replicates. A. Mean and standard error (n=6) of effective numbers of species for S = taxa richness, He and De = effective number of species for Shannon's Diversity Index and Simpson's Diversity Index. B. Taxa evenness. C. Exotic/total individual species frequency and exotic/total percent foliar cover.

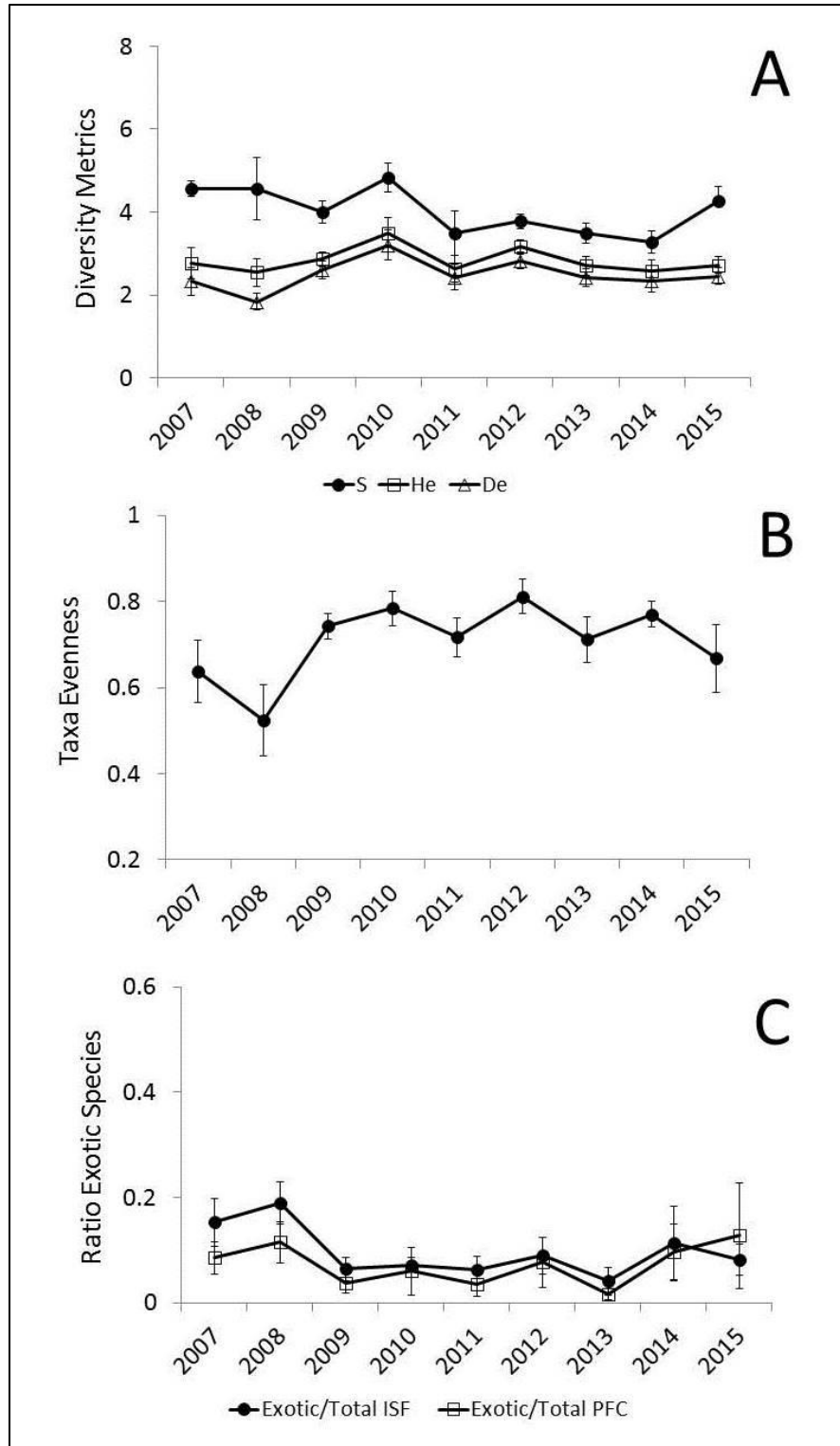


Figure 6. Diversity measures for aquatic vegetation occurring in Round Spring, Ozark National Scenic Riverways, Missouri. Values are derived from 1 m² replicates. A. Mean and standard error (n=6) of effective numbers of species for S = taxa richness, He and De = effective number of species for Shannon's Diversity Index and Simpson's Diversity Index. B. Taxa evenness. C. Exotic/total individual species frequency and exotic/total percent foliar cover.

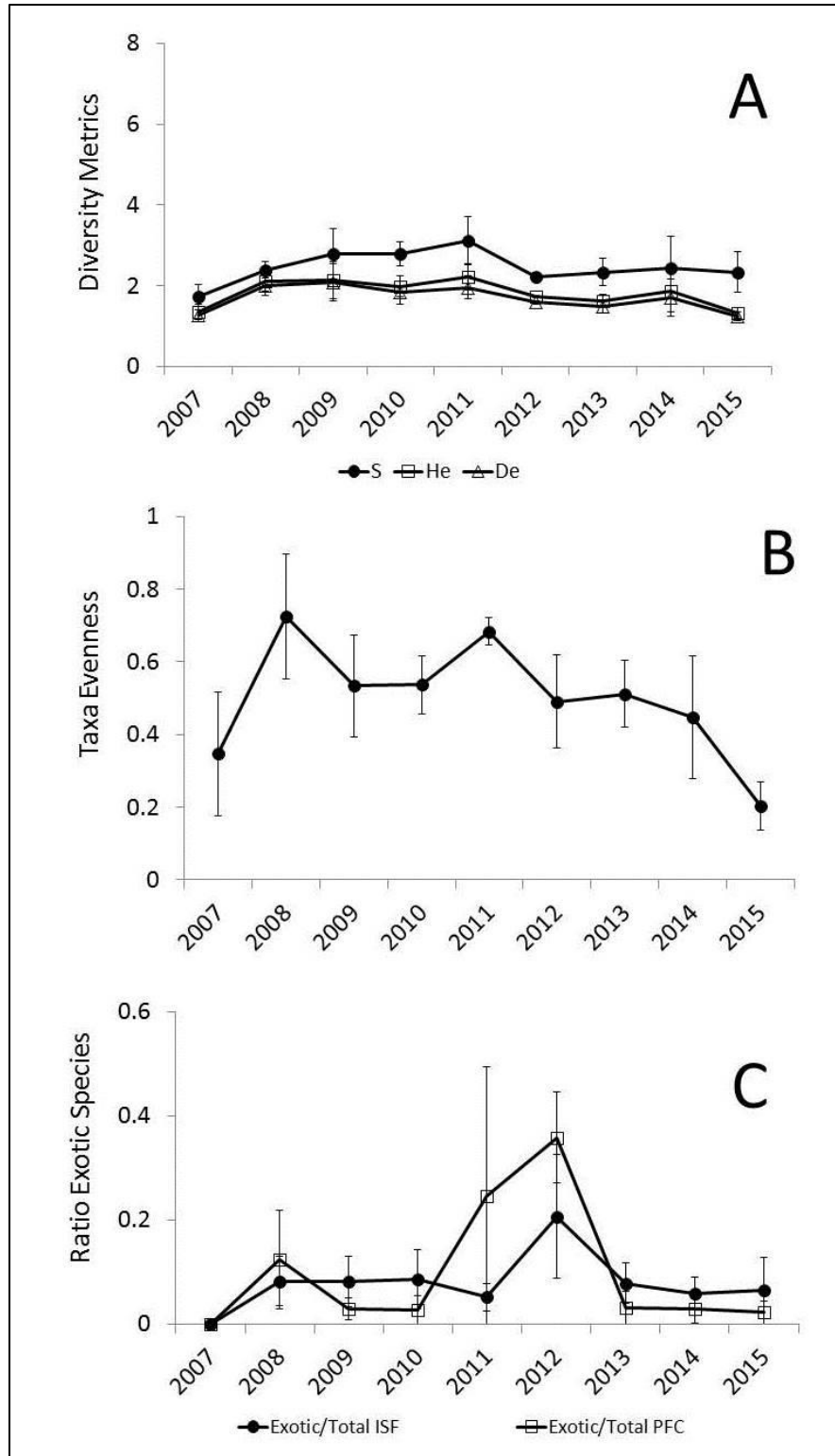


Figure 7. Diversity measures for aquatic vegetation occurring in Welch Spring, Ozark National Scenic Riverways, Missouri. Values are derived from 1 m² replicates. A. Mean and standard error (n=6) of effective numbers of species for S = taxa richness, He and De = effective number of species for Shannon's Diversity Index and Simpson's Diversity Index. B. Taxa evenness. C. Exotic/total individual species frequency and exotic/total percent foliar cover.

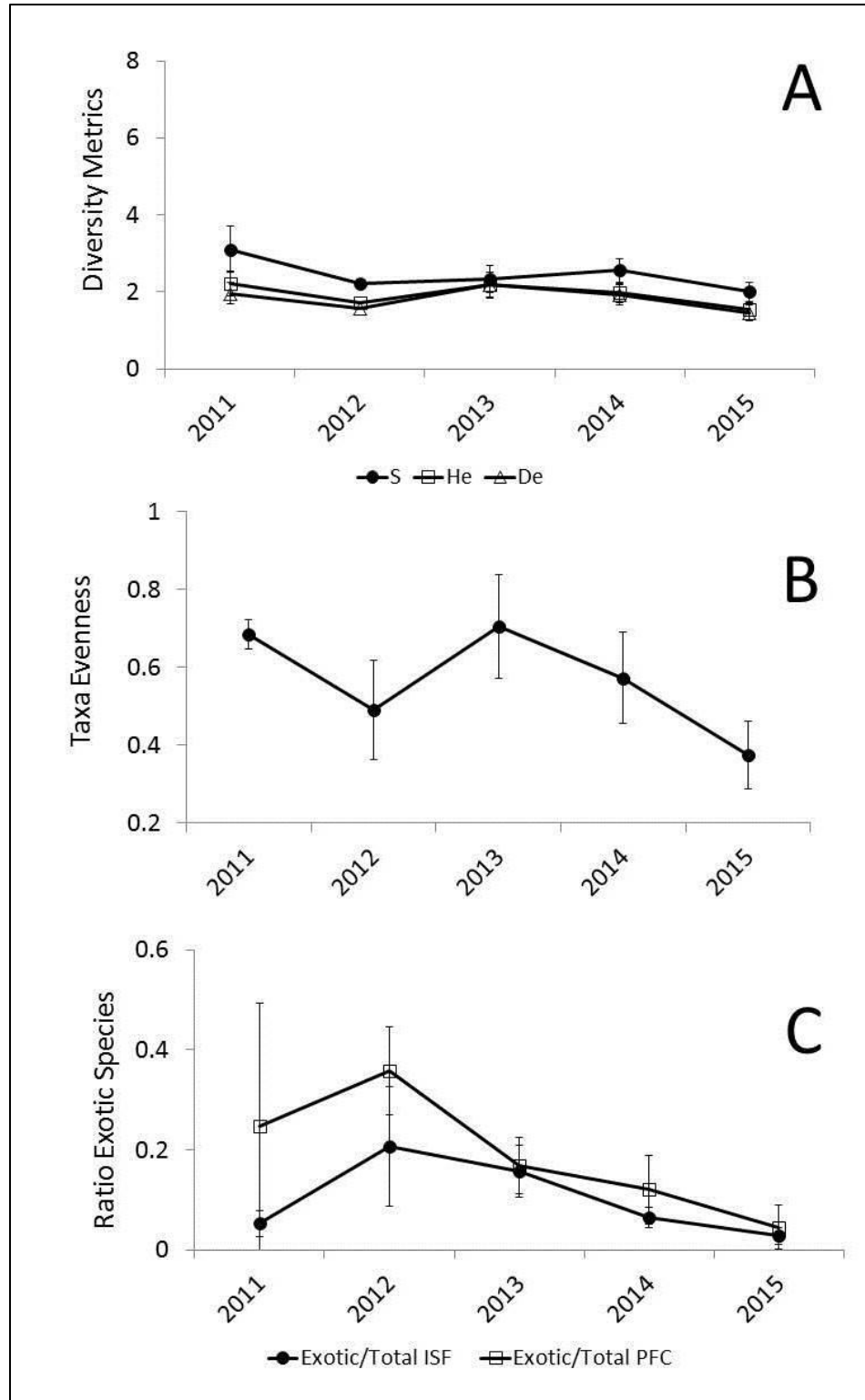


Figure 8. Diversity measures for aquatic vegetation occurring in Phillips Spring, Ozark National Scenic Riverways, Missouri. Values are derived from 1 m² replicates. A. Mean and standard error (n=6) of effective numbers of species for S = taxa richness, He and De = effective number of species for Shannon's Diversity Index and Simpson's Diversity Index. B. Taxa evenness. C. Exotic/total individual species frequency and exotic/total percent foliar cover.

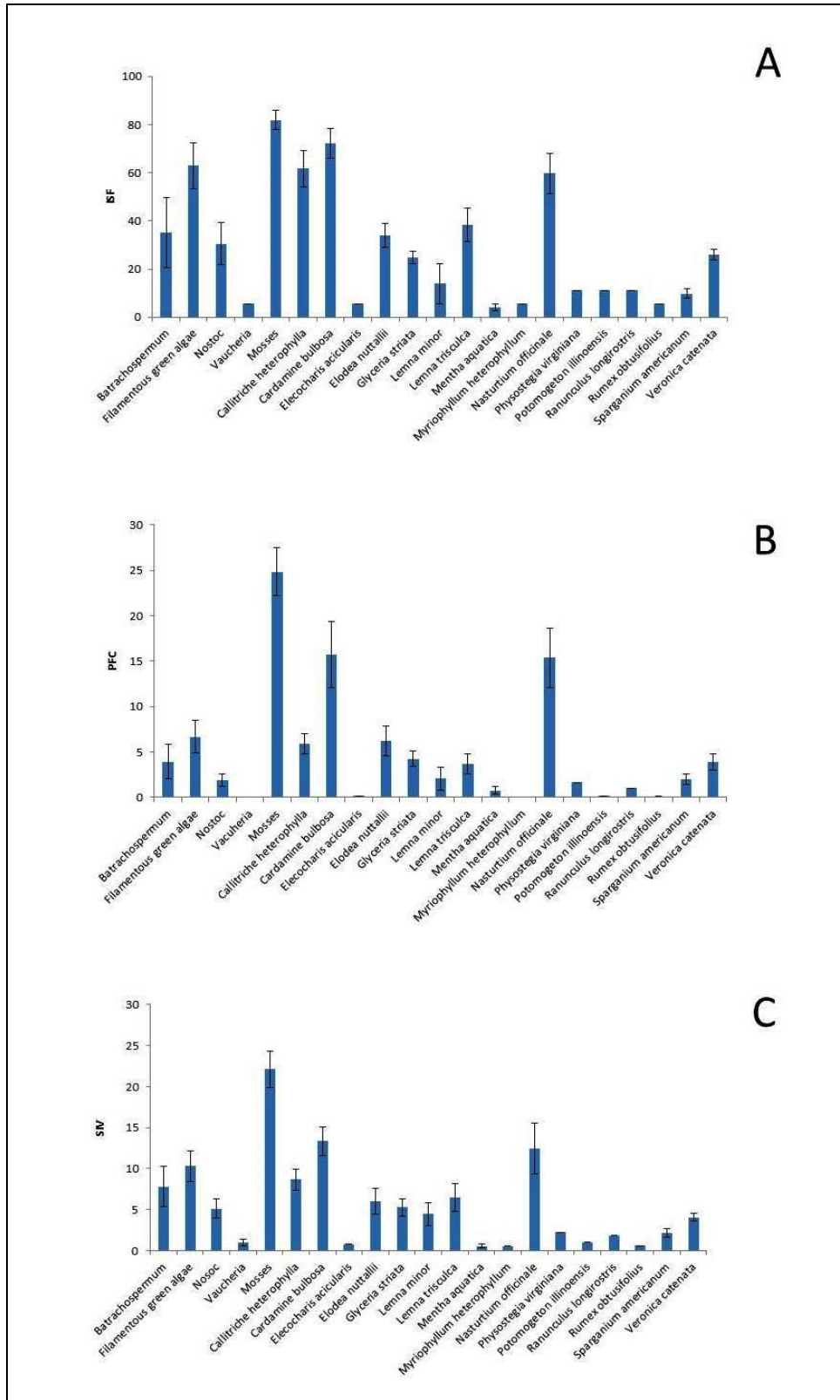


Figure 9. Mean individual species measures and standard errors (n=6) for Alley Spring, Ozark National Scenic Riverways, Missouri, 2007-2015. Values are derived from 1 m² replicates. A. Individual species frequency (ISF), B. percent foliar cover (PFC), C. Species importance value.

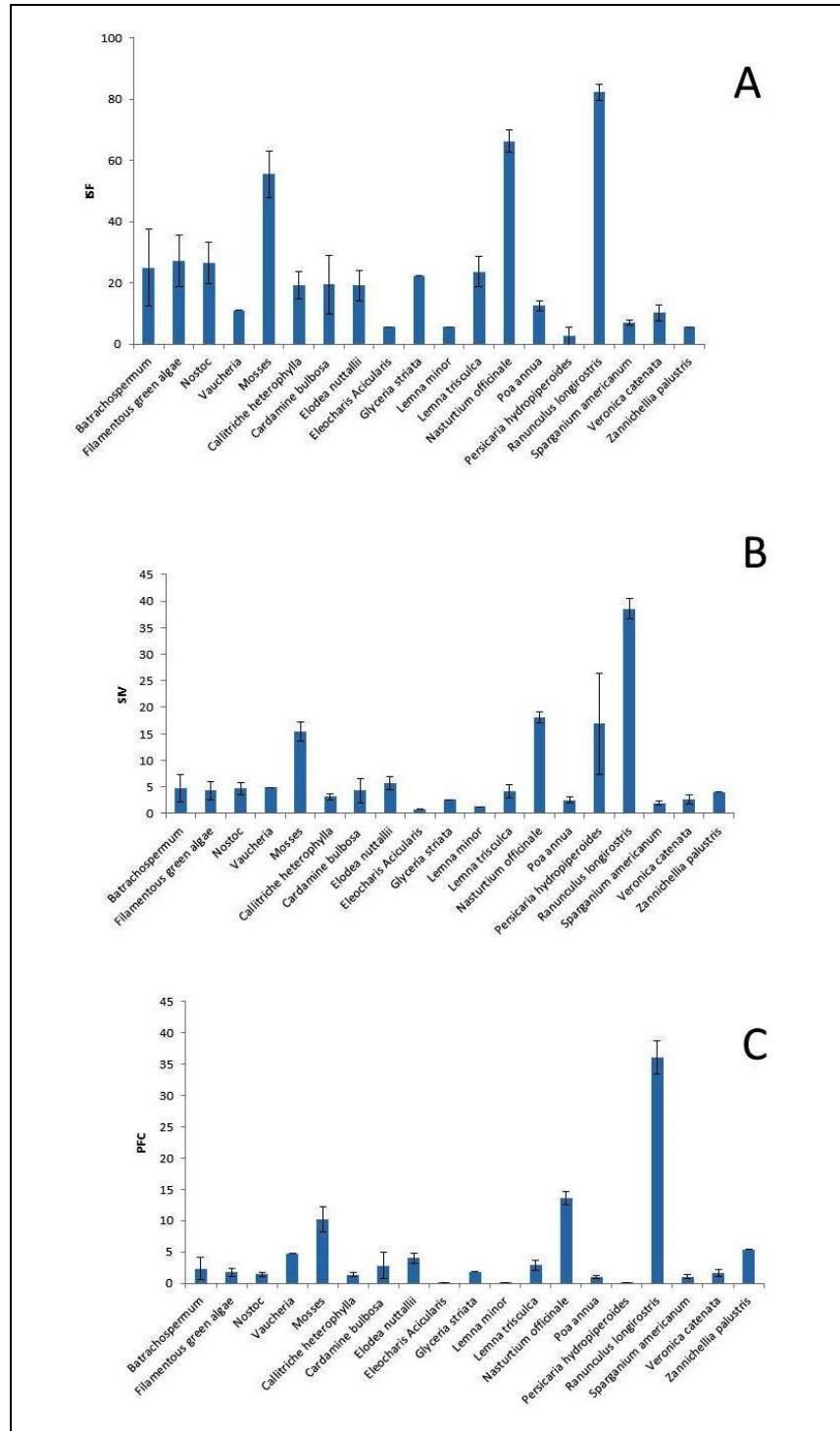


Figure 10. Mean individual species measures and standard errors (n=6) for Big Spring, Ozark National Scenic Riverways, Missouri, 2007-2015. Values are derived from 1 m² replicates. A. Individual species frequency (ISF), B. Percent foliar cover (PFC), C. Species importance value.

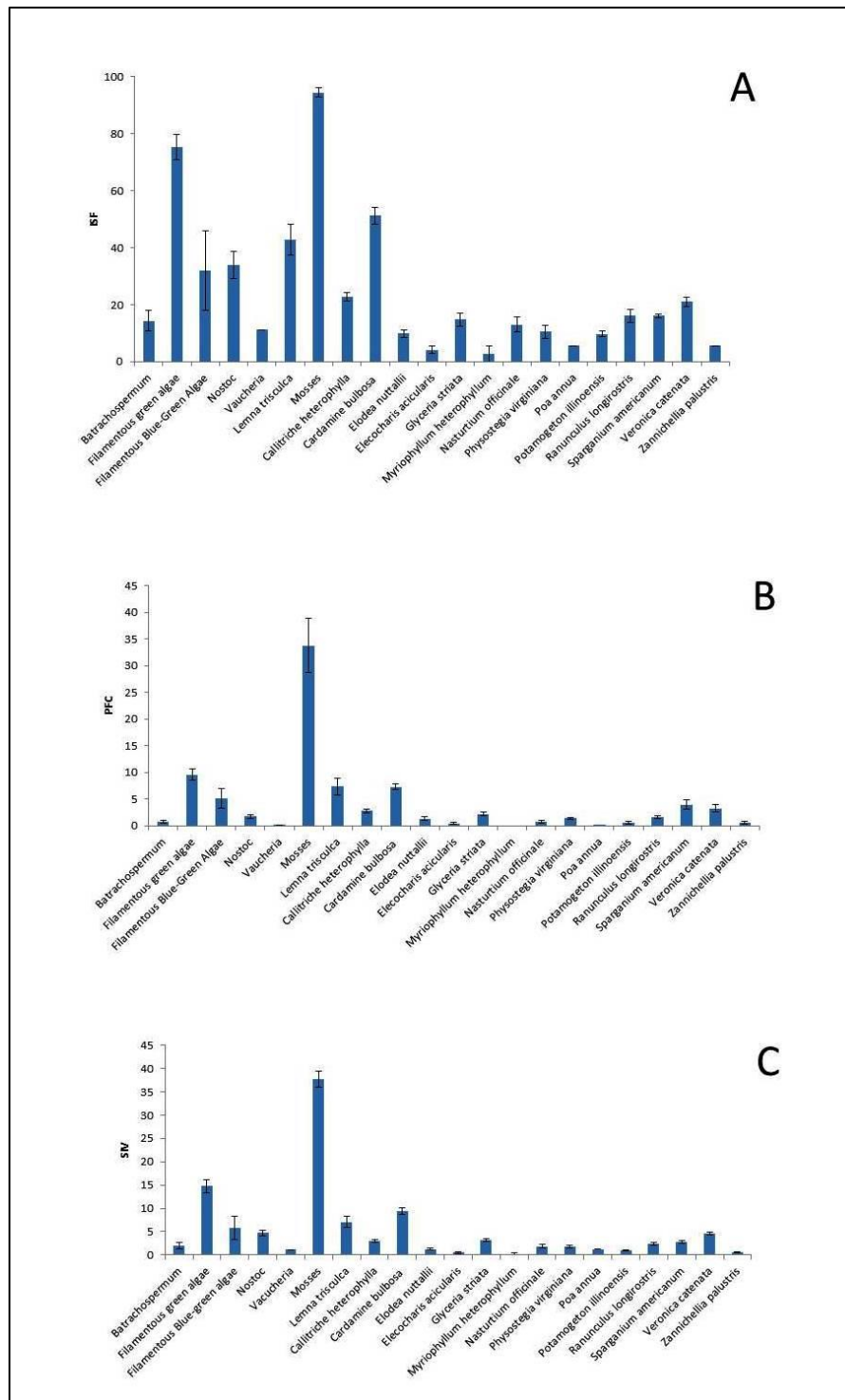


Figure 11. Mean individual species measures and standard errors (n=6) for Blue Spring, Ozark National Scenic Riverways, Missouri, 2007-2015. Values are derived from 1 m² replicates. A. Individual species frequency (ISF), B. Percent foliar cover (PFC), C. Species importance value.

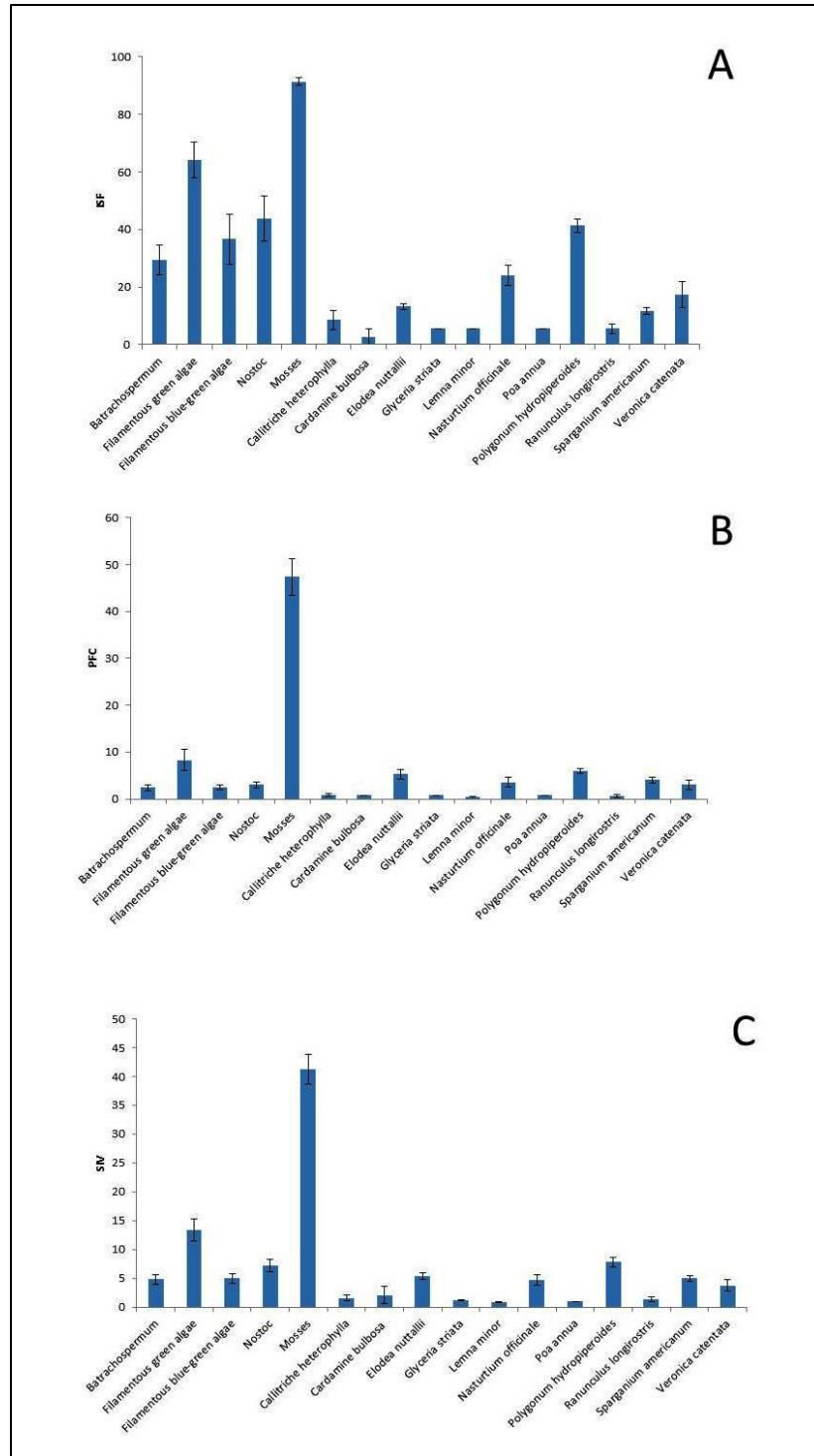


Figure 12. Mean individual species measures and standard errors (n=6) for Pullite Spring, Ozark National Scenic Riverways, Missouri, 2007-2015. Values are derived from 1 m² replicates. A. Individual species frequency (ISF), B. Percent foliar cover (PFC), C. Species importance value.

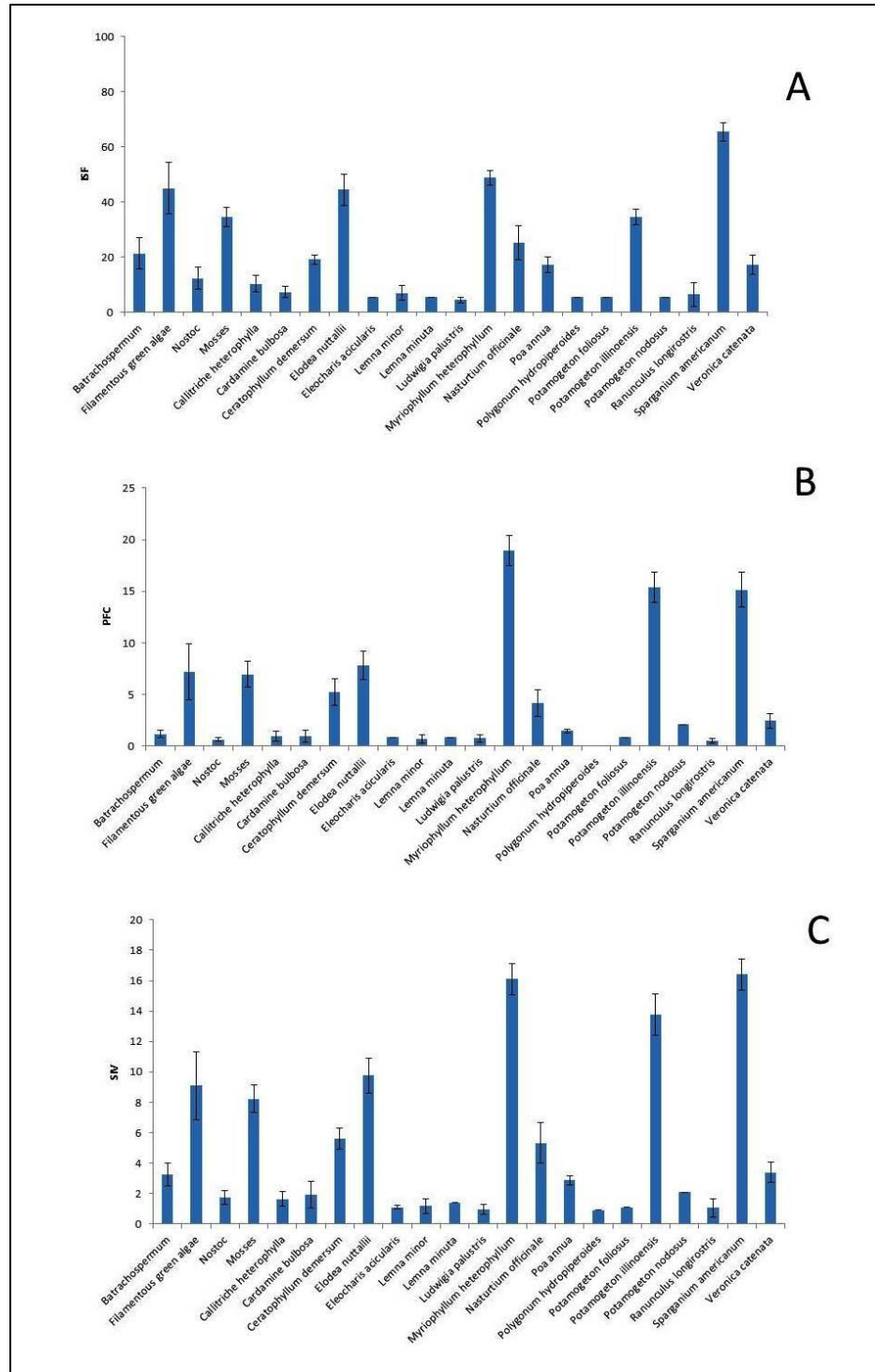


Figure 13. Mean individual species measures and standard errors (n=6) for Round Spring, Ozark National Scenic Riverways, Missouri, 2007-2015. Values are derived from 1 m² replicates. A. Individual species frequency (ISF), B. Percent foliar cover (PFC), C. Species importance value.

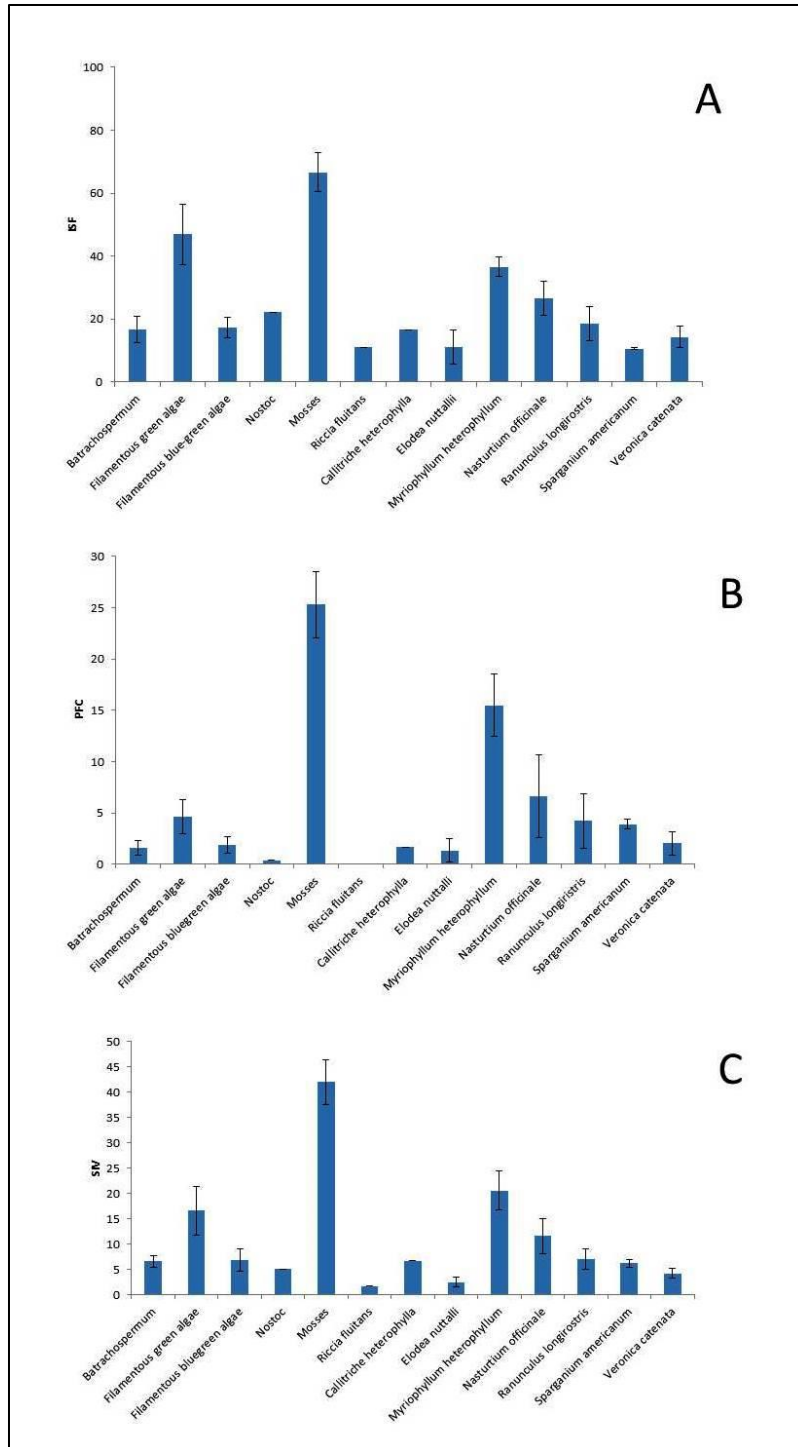


Figure 14. Mean individual species measures and standard errors (n=6) for Welch Spring, Ozark National Scenic Riverways, Missouri, 2007-2015. Values are derived from 1 m² replicates. A. Individual species frequency (ISF), B. Percent foliar cover (PFC), C. Species importance value.

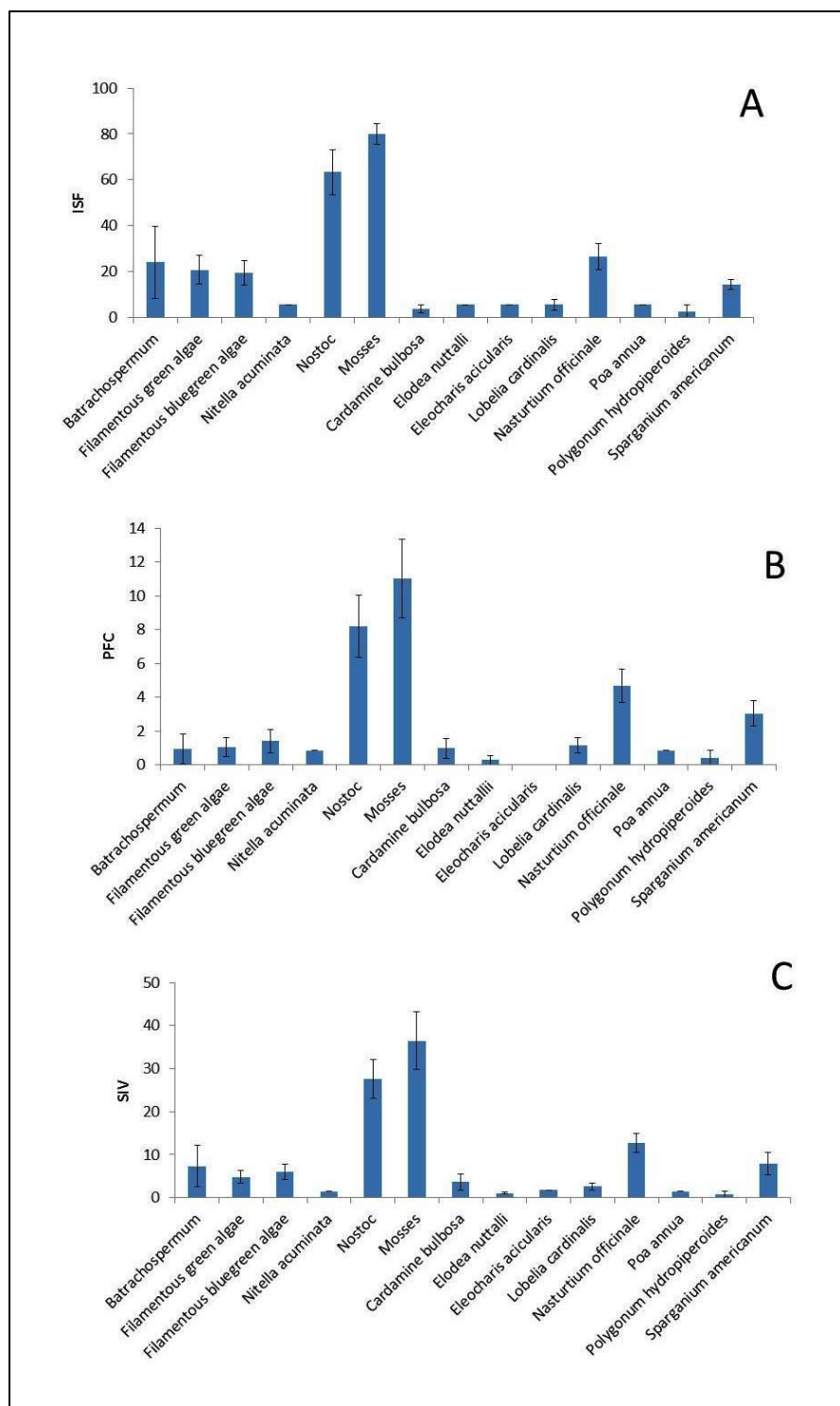


Figure 15. Mean individual species measures and standard errors (n=6) for Phillips Spring, Ozark National Scenic Riverways, Missouri, 2011-2015. Values are derived from 1 m² replicates. A. Individual species frequency (ISF), B. Percent foliar cover (PFC), C. Species importance value.

Conclusions

The springs share many taxa in common such as mosses, but the vegetation communities that occur in them and their relative abundances are quite different. We suggest this reflects the broad natural habitat diversity and physical and chemical stability of the springs. Watershed-level characteristics (recharge zone), local physical habitat factors including substrate size, canopy cover, and other unknown contributing factors may play important yet undetermined roles in structuring these communities. Since many of the taxa are shared in common among the springs, geographic location of taxa does not appear to be a factor. Collecting and analyzing additional monitoring data is required to determine the importance and relative contribution of the environmental factors influencing the springs and their vegetation communities. Additional monitoring also will allow insight into any patterns that may exist in plant community structure among these springs. The data presented in this report provides an important baseline dataset to detect anthropogenic disturbances in these springs, potentially ensuring their protection.

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