Vegetation Biodiversity Response to Excessive Flooding in Permanent and Ephemeral Wetlands

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Abstract

Ephemeral wetlands vary greatly in water depth and animal diversity in a highly dynamic habitat. The vegetation response of these wetlands to flooding in comparison to their more permanent counterparts is poorly understood. Increased precipitation resulted in a significant mean wetland water level increase in 2014 compared to 2013. In both these years, we surveyed vegetation in 24 permanent and 33 ephemeral wetlands in the Chippewa Moraine region of Wisconsin. In general, cover, species richness, and Shannon and Simpson diversity indices were all significantly higher in permanent wetlands than ephemeral ponds. After one year of extensive flooding, we observed a loss of both species richness and cover in both ephemeral and permanent wetlands. Ephemeral wetlands exhibited slightly more biodiversity loss from flooding than permanent wetlands, although these differences were not significant. These results suggest wetland vegetation is affected by flooding. Our study provides a baseline of information for studies exploring future environment change.

Keywords: ephemeral, wetland, flooding, and plant communities

Introduction

Experts have long recognized that hydrology is one of the most important factors influencing wetlands (Mitsch and Gosselink 2015). Flooding affects vegetation in many ways. It causes a mass introduction of sediment in the water that blocks out necessary sunlight for photosynthesis (DeJager, Thomsen & Yin, 2012). Flooding also erodes the soil that holds these plants until they are uprooted, killing the plant. Understanding vegetation response to flooding can further improve the information on how we define and protect wetlands now (Veselka IV, Rentch, Grafton, Kordek, & Anderson, 2010). How vegetation responds to flooding in permanent and ephemeral wetlands tells us about their vulnerability to future climate fluctuations. Observing plant biodiversity response to flooding will help us understand how much diversity is distributed between wetland types (MacRoberts, MacRoberts, Rudolph, & Peterson, 2014).

Ephemeral wetlands are a source of unique plant biodiversity due to their frequently fluctuating water levels (Lukács, et al.). Ephemeral water levels periodically provide wet or dry conditions. In many human expansion situations, ephemeral wetlands have been replaced by permanent wetlands to prevent the net loss of wetlands for legal purposes. Permanent wetlands are more species-rich, but do not typically sustain flood resistant life for periodic flooding (Drinkard, Kershner, Romito, Nieset, & de Szalay, 2011). In contrast, ephemeral ponds hold plant life adapted to periodic flooding (Siebel & Bouwma, 1998)seedlings and vegetative propagules of woody species in a hardwood flood-plain forest along the Upper Rhine in France revealed that the occurrence of most species is significantly correlated to elevation above river level and light transmission in summer. Species confined to higher-lying sites which are only occasionally and briefly flooded in the growing season show most damage upon flooding. Tall herb species occur on sites where more than 5% daylight reaches the herb layer and they only reach a dense cover where flooding is occasional. The occurrence of woody juveniles is negatively correlated with tall herb cover and largely confined to more shaded sites or more frequently flooded sites. The results indicate that both shading and flooding are important for regeneration of woody species and for maintaining species diversity in hardwood flood-plain forests.","DOI":"10.2307/3237280","ISSN":"1654-1103","language":"en","author":[{"family":"Siebel","given":"Henk N."},{"family":"Bouwma","given":"Irene M."}],"issued":{"date-parts":[["1998",10,1]]}}}],"schema":"https://github.com/citation-style-language/schema/raw/master/csl-citation.json"} . Ephemeral conditions limit the abundance of competitive wetland species, giving opportunity for adapted threatened and endangered plants to flourish (Daoud-Bouattour et al., 2014). Different wetland types could have diverse vegetation responses to flooding. Permanent wetland vegetation may be less resistant because permanent wetlands do not experience as dramatically fluctuating water levels. On the other hand, ephemeral wetlands may be more susceptible because they are smaller in size and have lower species richness compared to permanent wetlands.

In this study, plant life in ephemeral and permanent wetlands was surveyed in years with average and above average precipitation. The plant data were used to calculate total cover, richness, and species diversity indices. Differences in these variables before and after flooding were analyzed between wetland types. We hypothesized that permanent wetlands would have significantly more vegetation biodiversity loss (species richness, total cover, Shannon's and Simpson's diversity indices) than ephemeral from flooding, because permanent wetland vegetation may be less adapted to extreme water level fluctuations than ephemeral wetland vegetation.

Methods

Sample collection

Data were collected as part of an ongoing study of permanent and ephemeral wetlands called the Chippewa Ephemeral Ponds Project, (supported by the NSF under Grant DEB-1256142.) This study surveyed 57 wetlands (24 permanent and 33 ephemeral) in the Chippewa Moraine State Recreation Area during the summers of 2013 and 2014. Quadrats were sampled along stratified-random transects so as to derive at least ten quadrats per wetland. At each sampling location, terrestrial and aquatic surface vegetation in a 1 m^2 quadrat was recorded for presence/absence of understory plants (< 1.5 m tall). A modified-Daubenmire method (Daoud-Bouattour et al., 2014) was used to obtain visual percent-cover estimates for each species. Aquatic plants that were present on the water's surface were recorded along with the water depth.

Data analysis

Data were compiled for all wetlands using Microsoft Excel, into five categories: water depth, species richness, total cover, Shannon's diversity (Drinkard et al., 2011)(), and Simpson diversity (Schen & Berger, 2014) () indices were calculated. Water depth is the measurement of water deepness (cm). Species richness is the number of different plant species. Total cover measures the amount of vegetation that covers the ground. Shannon's and Simpson's diversity indices are equations used to measure the community species diversity. Statistical analysis was conducted in the statistical software package R. A complete factorial two-way analysis of variance (ANOVA) was used to examine variance in richness, percent cover, and diversity indices between wetland type (permanent and ephemeral) and year of sample (2013-2014).

Results

Rainfall increased dramatically between 2013 and 2014, causing flooding in the Chippewa Moraine. Mean wetland water depth was significantly higher in 2013 (7.5 cm, SE = 1.4 cm) than in 2014 (28.5 cm, SE = 3.2 cm, $P < 0.001$, paired T = 2.00, df = 56, Figure 1). All categories of biodiversity showed a loss from 2013 to 2014, although not all were significant losses.

Figure 1

Figure 1

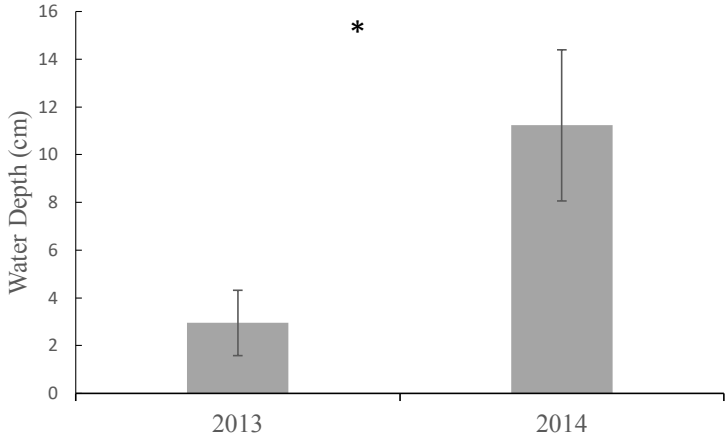

Figure 1. Mean water depths in 57 wetlands in 2013 and 2014, demonstrating a significant increase in 2014. Error bars are the standard error. Star indicates significant difference at $P < 0.05$.

Species richness was significantly lower in ephemeral wetlands ($F_{1,110} = 6.37$, $P = 0.013$), and had a significant loss between years ($F_{1,110} = 5.94$, $P = 0.016$, Figure 2). Ephemeral ponds lost more species, although this interaction term was not significant ($F_{1,110} = 0.24$, $P = 0.625$).

Figure 2

Figure 2

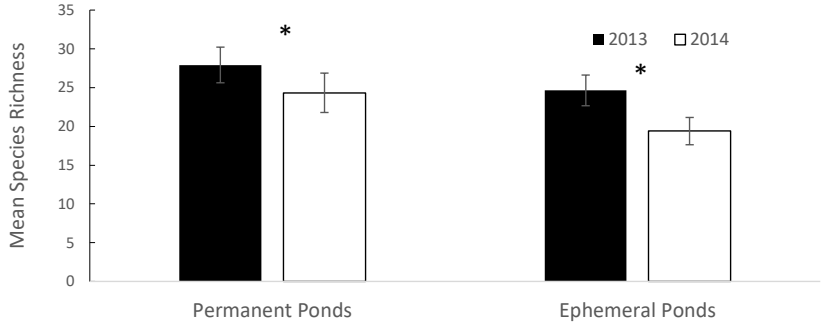

Figure 2. Mean species richness in permanent and ephemeral wetlands in 2013 (pre-flood) and 2014 (flooded). Error bars are the standard error. Star indicates significant difference at $P < 0.05$.

Total percent-cover of vegetation also had a significant difference between class ($F_{1,110} = 36.67$, $P \leq 0.001$) and year ($F_{1,110} = 6.74$, $P = 0.011$, Figure 3). Permanent wetlands lost a larger amount of cover than ephemeral ponds, although this difference was not significant ($F_{1,110} = 0.21$, $P = 0.655$).

Figure 3

Figure 3

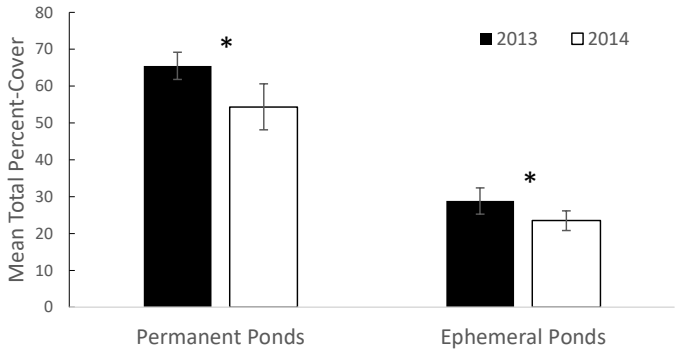

Figure 3. Mean total percent-cover in permanent and ephemeral wetlands in 2013 (pre-flood) and 2014 (flooded). Error bars are the standard error. Star indicates significant difference at $P < 0.05$.

Shannon and Simpson diversity indices were both significantly higher in permanent wetlands than ephemeral ponds (Shannon: $F_{1,110} = 15.80$, $P \leq 0.001$ and Simpson: $F_{1,110} = 16.11$, $P \leq 0.001$). There was no significant decrease in either diversity index from 2013 to 2014 (Shannon: $F_{1,110} = 1.68$, $P = 0.197$ and Simpson: $F_{1,110} = 0.964$, $P = 0.328$, Figures 4 and 5). Neither interaction was significant.

Figure 4

Figure 4

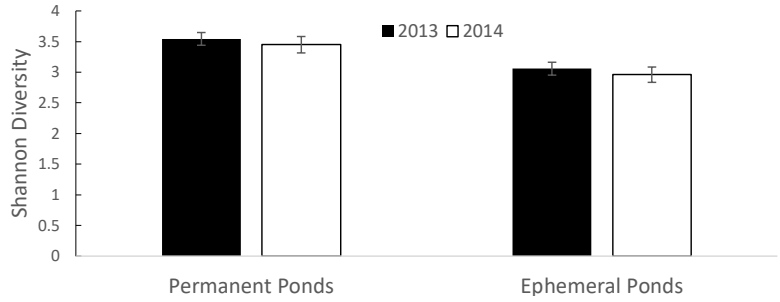

Figure 4. Mean Shannon diversity index in permanent and ephemeral wetlands in 2013 (pre-flood) and 2014 (flooded). Error bars are the standard error.

Figure 5

Figure 5

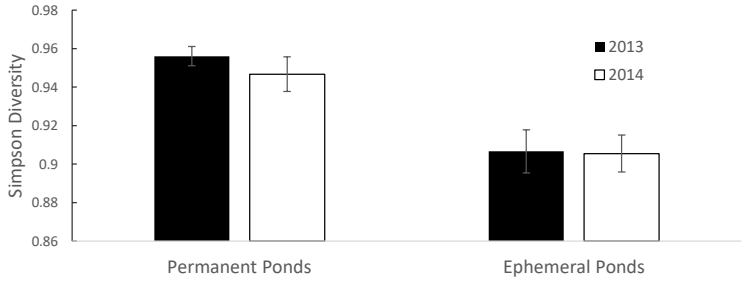

Figure 5. Mean Simpson diversity index in permanent and ephemeral wetlands in 2013 (pre-flood) and 2014 (flooded). Error bars are the standard error.

Discussion

Flooding in the Chippewa Moraine resulted in a loss of plant biodiversity in both ephemeral and permanent wetlands. Wetlands had significant losses in species richness and total cover from 2013 to 2014. Ephemeral wetlands lost slightly more species richness than permanent wetlands. The severity of flood disturbance could have varied for wetland types. Permanent wetlands did not lose as large a proportion of biodiversity because they had a larger amount of plant biodiversity in 2013 (pre-flood). Because ephemeral ponds have a lower plant biodiversity to begin with, it is more difficult to resist large amounts of species loss (Rhazi et al., 2011).

These small ephemeral plant communities will have less vegetation available to recover from large plant biodiversity loss, whereas permanent wetlands have lost a large amount of vegetation but still have a large amount of vegetation to recover from flood disturbance.

Many wetland plant communities adapt to aspects of flooding. Flooding carries increased nutrients that wetland plant communities use to stimulate growth (Drinkard et al., 2011). Many wetland plants have adapted to survive with poorer sunlight in flood conditions (Siebel & Bouwma, 1998) seedlings and vegetative propagules of woody species in a hardwood flood-plain forest along the Upper Rhine in France revealed that the occurrence of most species is significantly correlated to elevation above river level and light transmission in summer. Species confined to higher-lying sites which are only occasionally and briefly flooded in the growing season show most damage upon flooding. Tall herb species occur on sites where more than 5% daylight reaches the herb layer and they only reach a dense cover where flooding is occasional. The occurrence of woody juveniles is negatively correlated with tall herb cover and largely confined to more shaded sites or more frequently flooded sites. The results indicate that both shading and flooding are important for regeneration of woody species and for maintaining species diversity in hardwood flood-plain forests.","DOI":"10.2307/3237280","ISSN":"1654-1103","language":"en","author":[{"family":"Siebel","given":"Henk N."},{"family":"Bouwma","given":"Irene M."}],"issued":{"date-parts":[["1998",10,1]]}}],"schema":"https://github.com/citation-style-language/schema/raw/master/csl-citation.json"} . These plant adaptations could be from the consistent exposure to flood disturbance (Toogood & Joyce, 2009). The isolated Chippewa Moraine wetlands do not receive regular flood disturbances, so flooding results in significant loss of plant biodiversity when flood disturbance occurs. These plant communities may lack adaptations to endure the negative effects of flooding and take advantage of flooding for seed dispersal or nutrient absorption. The study of vegetation response to flooding should be continued in order to understand if the wetland plant communities of the Chippewa Moraine will sustain or diminish from flood disturbance.

Shannon and Simpson diversity indices showed no significant differences from 2013 to 2014, although there were in losses in total cover and species richness. Both Shannon and Simpson indices account for evenness in the abundance of species and species richness. Losses in total cover could have created a greater evenness in the species abundances by suppressing some of the more abundant species. Even though there were losses in total cover and species richness, the amount of plant life post-

flooding was more evenly distributed. Increased evenness combined with decreased richness meant that there were no significant changes from year to year in the Shannon and Simpson diversity indices.

Continued flooding in these wetlands could have implications over time. There was a significant plant species richness and total plant cover loss in both types of wetlands (permanent and ephemeral). Due to their smaller size and initially lower species richness, ephemeral pond plant communities may be less resistant to disturbances like flooding. In the conservation of ephemeral and permanent wetlands, the progression of flooding and plant biodiversity should be monitored and observed (MacRoberts et al., 2014). As the climate fluctuates, flooding will have an impact on these wetlands, but the long-term consequences remain to be seen. Increased flooding frequency is likely to decrease species richness and total vegetation cover, regardless of pond type.

References

Daoud-Bouattour, A., Bottollier-Curtet, M., Jamaa, H. F.-B., Ghrabi-Gammar, Z., Saad-Limam, S. B., Rhazi, L., & Muller, S. D. (2014). Effects of hydrology on recruitment of Pilularia minuta Durieu (Marsileaceae), an endangered plant of Mediterranean temporary pools. *Aquatic Botany, 112*, 76–83. https://doi.org/10.1016/j.aquabot.2013.08.001

Drinkard, M. K., Kershner, M. W., Romito, A., Nieset, J., & de Szalay, F. A. (2011). Responses of plants and invertebrate assemblages to water-level fluctuation in headwater wetlands. *Journal of the North American Benthological Society, 30*(4), 981–996.

Lukács, B. A., Sramkó, G., & Molnár V, A. (2013). Plant diversity and conservation value of continental temporary pools. *Biological Conservation, 158*, 393–400. https://doi.org/10.1016/j.biocon.2012.08.024

MacRoberts, B. R., MacRoberts, M. H., Rudolph, D. C., & Peterson, D. W. (2014). Floristics of Ephemeral Ponds in East-central Texas. *Southeastern Naturalist, 13*(5), 15–25.

Mitsch, W.J. and J.G. Gosselink. 2015. Wetlands, 5th ed. John Wiley and Sons, Inc. Hoboken, NJ.

Rhazi, L., Grillas, P., Saber, E.-R., Rhazi, M., Brendonck, L., & Waterkeyn, A. (2011). Vegetation of Mediterranean temporary pools: a fading jewel? *Hydrobiologia, 689*(1), 23–36. https://doi.org/10.1007/s10750-011-0679-3

Schen, M., & Berger, L. (2014). Calculating Biodiversity in the Real World. *Science Teacher, 81*(7), 25.

Siebel, H. N., & Bouwma, I. M. (1998). The occurrence of herbs and woody juveniles in a hardwood floodplain forest in relation to flooding and light. *Journal of Vegetation Science, 9*(5), 623–630. https://doi.org/10.2307/3237280

Toogood, S. E., & Joyce, C. B. (2009). Effects of raised water levels on wet grassland plant communities. *Applied Vegetation Science, 12*(3), 283–294.

Veselka IV, W., Rentch, J. S., Grafton, W. N., Kordek, W. S., & Anderson, J. T. (2010). Using two classification schemes to develop vegetation indices of biological integrity for wetlands in West Virginia, USA. *Environmental Monitoring & Assessment, 170*(1-4), 555–569. https://doi.org/10.1007/s10661-009-1257-2