

# **Altering Hydrology in Breeding Ponds to Benefit Imperiled Amphibians During Drought**

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## ABSTRACT

The project is located within the Apalachicola National Forest (ANF) just south of Tallahassee, FL. The region is characterized by a rolling sand hill terrain containing many isolated, depressional wetlands. Wetland hydroperiods are driven by fluctuations in the underlying aquifer. At this study's outset, we hypothesized that three ephemeral wetlands containing pre-installed synthetic rubber pond liners would exhibit increased hydroperiods relative to similar, selected unlined control ponds. Furthermore, we hypothesized that pond-breeding amphibians would breed more successfully in lined ponds versus unlined ponds due to hydroperiod extension. To test our hypotheses, we monitored water level, rainfall, and amphibian breeding in three lined/unlined pond pairs for six months out of each of three consecutive years (2017-2019). Analysis of hydrological and amphibian monitoring data from lined/unlined pond pairs showed that lined ponds held water significantly longer than unlined ponds. Lined ponds, having an artificial confining layer impermeable to water, acted as shallow catchments persistently pooling rainwater. Unlined ponds acted more like sieves allowing for rapid percolation of rainwater into the ground. Unlined ponds filled infrequently, only if the aquifer rose to an elevation greater than pond bottoms. Amphibian monitoring data from lined and unlined ponds also clearly showed that lined ponds experienced significantly greater amphibian breeding activity than unlined ponds throughout the study. We conclude that liners extended hydroperiods of our lined study ponds and allowed for increased breeding opportunities for resident amphibians compared to unlined ponds. We also found that liners, if installed properly, do not detrimentally alter ephemeral pond amphibian communities, but rather can enhance habitat to benefit targeted amphibian populations.

## **ACKNOWLEDGEMENTS**

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## INTRODUCTION

This project is part of a pre-existing effort to repatriate the imperiled striped newt back into its historical range within the Apalachicola National Forest (ANF) (Means et al. 2017). The ANF is the former western stronghold of the striped newt (Means et al. 2013). Coastal Plains Institute (CPI) sampling data show that up until 1999, individuals of the western striped newt in the ANF were relatively abundant. However, since that time, the striped newt in the ANF has undergone a mysterious decline.

One possible cause of the striped newt decline in the ANF is drought. Drought has been linked to some amphibian declines and extirpations of populations (Lips et al. 2005). Since 1998, North Florida experienced two prolonged, excessive droughts during the 10-year period from 1998-2008 (M. Griffin, Florida Climate Center, pers. comm.). Severe droughts lasted from 1998-2001 and 2006-2008. Hydroperiods were much shorter in ephemeral wetlands across the Munson Sandhills during the droughts (R. C. Means and D.B. Means, unpublished data). Rarely were there prime opportunities for striped newts to breed, and when there were opportunities, CPI biologists did not detect larval newts for over 15 years, despite considerable sampling effort (Means 2007, Means et al., 2008, Means et al. 2015). With the onset of climate change, hydroperiods are expected to shorten in ephemeral wetlands (Bates et al. 2008). In the sandhills habitat, climate-induced drought likely will have negative impacts on ephemeral pond-breeding amphibians. These habitat specialists cannot breed unless the breeding pond fills during the appropriate season and stays hydrated long enough for aquatic larvae to reach metamorphosis into their terrestrial phase.

Hydrological work conducted by Katherine Milla (Florida A&M University) and Steve Kish (Florida State University) indicated that Munson Sandhills ponds are aquifer-driven. They predominately respond to fluctuations in the groundwater table over time, not to individual rainfall events (pers. comm). With that knowledge, CPI hypothesized that installation of liners would create an artificial geological confining layer, currently non-existent in the sandy soiled Munson Sandhills, that would effectively change the way in which lined ponds would hydrate. We believed that lined wetlands would develop longer hydroperiods. We hoped to increase hydroperiod in select striped newt repatriation wetlands for the purpose of giving newts more time and greater chances to survive repatriations in a formerly drought-stricken landscape.

During 2012 and as part of a larger striped newt repatriation study (see Means et al. 2012), CPI selected four wetlands as repatriation (recipient) wetlands based on historic striped newt breeding habitat and suitability for synthetic liner installation. We installed synthetic (EPDM), 40-mil, “fish grade” rubber liners underneath the central portions of three of four selected repatriation wetlands (Ponds 18, 75, and 182) that had been gripped by severe drought at the time of installation. Liners were square-shaped and measured 40 feet long by 40 feet wide. We hypothesized that liners would boost recipient pond hydroperiods, thereby making them more drought resistant for the purpose of providing any repatriated newt larvae with enough time to reach metamorphosis. The fourth wetland, Pond 16, also was scheduled to receive a liner, but conditions there have been too wet to complete installation.

This current project tests our hypothesis that liners extend pond hydroperiods. By comparing

wetland hydrological data and amphibian community composition in three lined/unlined wetland pairs, this project tests the effectiveness of this management tool for the relocation, repatriation, and translocation of imperiled amphibian species expected to be negatively impacted by climate change-induced drought.

There is conservation benefit to be gained for the future management of the striped newt and other imperiled species through this study. Since the striped newt is not yet state-listed in Florida, a Species Action Plan (SAP) does not exist. However, state-listing for this salamander species is currently in process. The gopher frog (a Species of Greatest Conservation Need) and ornate chorus frog (a Species of Greatest Conservation Need) use the same wetlands, and also require sufficient hydroperiod. There is a clear need to evaluate the use of pond-liners as a hydroperiod enhancement technique to benefit Florida's imperiled ephemeral-pond breeding amphibians. Hydroperiod enhancement techniques, such as the use of pond liners, are expected to become more and more necessary in conservation projects as we move forward into the climate change era.

## **Objectives**

1. Utilize, maintain, and repair already-installed liners in three ponds to enhance repatriation sites for sufficient pond hydroperiod throughout critical larval metamorphosis lifestage.
2. Monitor amphibian populations in three lined and three unlined ponds with frog-call surveys, incidental observations, and monthly dipnet surveys to assess influence of increased hydroperiod in lined ponds versus ponds without liners.
3. Evaluate expected hydroperiod changes in lined ponds relative to paired, unlined reference ponds.

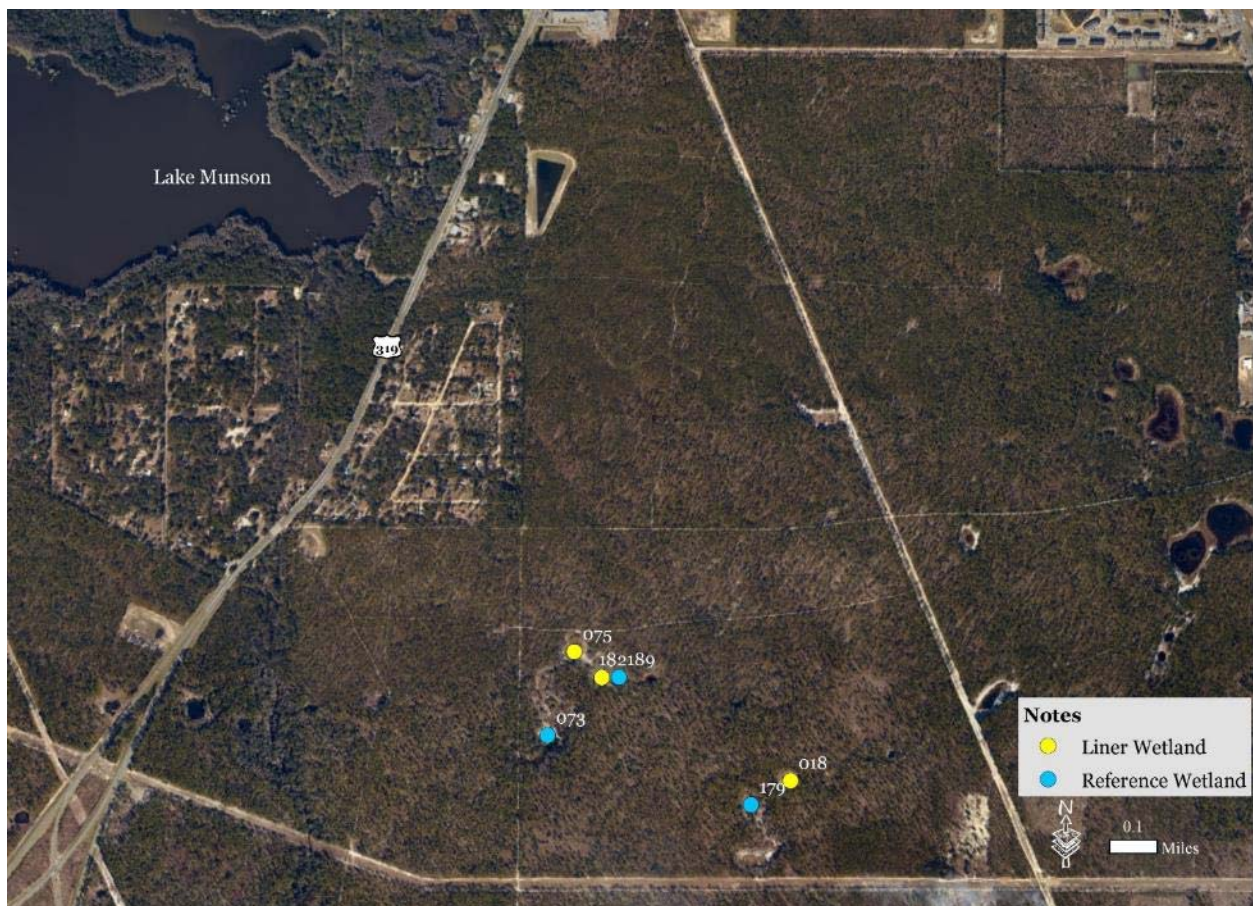
This report summarizes findings from 2017-2019. See Annual Reports for more detailed information about 2017 (Means and Means, 2017) and 2018 (Means and Means, 2018).

## METHODS

### Study Area

The project is located within the Apalachicola National Forest (ANF) just south of Tallahassee, FL in Leon County (Figure 1). The targeted habitat is longleaf pine sandhill with embedded ephemeral wetlands, located within the Munson Sandhills. The Munson Sandhills physiographic region is a rolling sandy soil terrain containing many isolated, depressional, ephemeral wetlands of all sizes. The sandy hills represent relict dunes deposited by higher sea level stands that occurred during the Pleistocene Epoch. Limestone underlies the region. There is a groundwater aquifer system beneath the sand hills which may represent either the Floridan Aquifer System, or some local surficial aquifer system. There are no known geological confining layers that exist between sandy, permeable surface soils and the underlying aquifer.

While the Munson Sandhills region is approximately 45,000 acres in size, this project is concentrated in an area of less than 600 acres. The six study wetlands range in size from 0.5 acres to 0.6 acres.



**Figure 1.** Map of the northeastern ANF showing the location of our study wetlands. All lined wetlands also are striped newt repatriation sites. Lined Pond 18 is paired with unlined Pond 179, lined Pond 75 is paired with unlined Pond 73, and lined Pond 182 is paired with unlined Pond 189.

## Hydrological Monitoring

To quantify the hydrological impact of liners, we selected nearby wetlands that were hydrologically similar to our lined wetlands to serve as reference/control wetlands. Pond 18 is paired with Pond 179 (Figure 2), Pond 75 is paired with Pond 73 (Figure 3), and Pond 182 is paired with Pond 189 (Figure 4).

On 20 December 2016, we installed one, 0-3.32' WaterMark ® Style "C" Stream Gauges in each of the six wetlands to begin quantitatively monitoring water levels. We attached each gauge to the top three feet of a four-foot section of PVC pipe using pre-drilled holes in the gauges and 2" galvanized screws. Using a mallet, we hammered the PVC pipe/stream gauges into the center of all six wetland basins until the gauge bottom (reading of 0.00") was flush with the lowest part of the wetland floor. All three reference wetlands were dry during time of installation. The three liner wetlands held small pools of water so we could not gain a visual reference of the wetland floor. We hammered the PVC pipe down until we could feel the bottom of the staff gauge was flush with the wetland floor. We were able to get an accurate read because the floor of these wetlands was firm. We did not hammer the PVC pipe deep enough to puncture the liners. Liners are covered by approximately 18" of organic soil covered by herbaceous vegetation.

We placed 5" rain gauges adjacent to wetlands. We checked pond water levels and rain gauges a minimum of once a week from January through June for three years (2017-2019). The monitoring effort corresponded to the opening of drift fences associated with the striped newt repatriation project. During site visits, we checked that the liners were intact and seemingly functional based on the appearance of pooled water above the liner locations. We also checked for physical damage from off-road vehicle use, which has been an issue in the past.





**Figure 2.** Pond 18 (top), a lined wetland, and its paired, unlined wetland Pond 179 (bottom). Before installation of the pond liner, these wetlands, which are within 1/10 of a mile from each other, were hydrologically similar.





**Figure 3.** Pond 75 (top), a lined wetland, and it's paired, unlined wetland Pond 73 (bottom). Before installation of the pond liner, these wetlands, which are less than 2/10 of a mile from each other, were hydrologically similar.





**Figure 4.** Pond 182 (top), a lined wetland, and its paired, unlined wetland Pond 189 (bottom). Before installation of the pond liner, these wetlands, which are less than 200 feet from each other, were hydrologically similar.

## **Amphibian Community Assessment**

We used monthly dipnet surveys of hydrated wetlands to detect larval and breeding adult amphibians in lined and unlined, reference wetlands (January through June 2017-2019). We sampled using a heavy duty dipnet (Memphis Net and Twine Co. HDD-2 model) with 3/16" mesh. The number of dipnet sweeps or time of sampling per paired lined/unlined wetland was held constant but varied between wetland pairs based on wetland size and hydration. We concentrated sweep efforts along pond periphery and herbaceous vegetation patches. To prevent harm, dipnetting did not take place during periods when striped newt breeding activity was occurring or when tiny larvae were present.

We conducted seasonal, nocturnal frog call surveys at all six ponds during prime breeding weather conditions to ascertain the presence of all adult anuran species. Frog call surveys were conducted between the hours of 10 pm and 12:30 am and involved recording the species and relative number per species heard calling during a 15-minute period (none, sporadic, and chorus). In order to reduce hour-of-night influence on survey results, time between call surveys at a lined wetland and its unlined pair did not exceed 15 minutes.

We conducted opportunistic searches around the pond perimeters during dipnetting and frog call surveys. We documented all amphibians observed by species and quantity, including egg masses, larvae, and adults. Because only the lined wetlands have drift fencing around them, we did not include data associated with fences (in bucket traps or observed along the fences themselves).



## RESULTS AND DISCUSSION

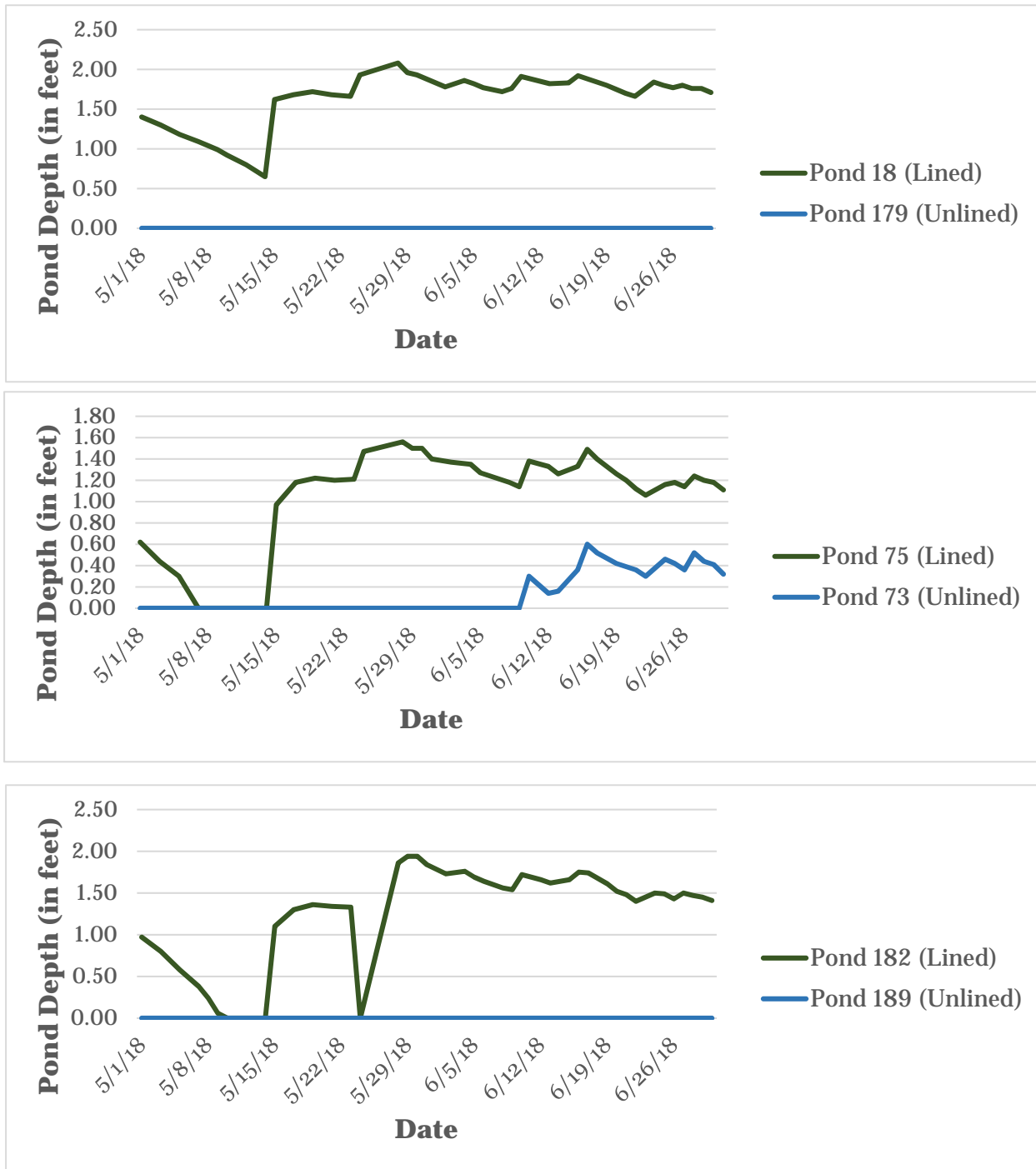
### Hydrological Monitoring

We collected pond level and rainfall data on 305 days between the months of January and June during the three-year project period (2017-2019). Pond 18 (lined) held at least some water for all 305 sampling days while its unlined reference wetland, Pond 179, held water for 12 days (Appendix A). Pond 75 was hydrated for 295 sampling days while its unlined, reference wetland, Pond 73, held water for 225 days (Appendix B). Lined Pond 182 was hydrated for 279 sampling days while its unlined reference wetland, Pond 189, held water for only 28 days (Appendix C).

Rainfall data analyzed in conjunction with pond water level data for all three years showed that rainfall is the primary driver for lined wetland water level and aquifer fluctuation is the primary driver for unlined wetland water levels. When the underlying aquifer was recessed well below pond bottoms, and unlined control ponds were dry, lined pond water levels rose instantaneously during rain events, whereas water levels of unlined ponds remained dry. Rainwater accumulating in unlined wetlands percolated rapidly into the ground (Figure 5). Occasional rains would be enough to perpetuate and rejuvenate shallow pond pools on top of liner basins for weeks or months while unlined ponds remained dry (Figure 6).



**Figure 5.** Unlined Pond 73. High water mark at 0.5-foot level consisting of affixed leaf litter on staff gauge revealed rapid percolation of rainwater that pooled during a 1.3-inch rainfall the day before. All liner ponds bumped up an average of 0.1 feet after the same rainfall event while all three unlined wetlands dried by the next day.



**Figure 6.** Water levels of lined/unlined pond pairs during a period of aquifer recharge. Rainfall pooled on liners creating persistent pools in lined ponds while rainfall percolated through unlined wetland bottoms. Unlined wetlands typically remained dry while the aquifer was recessed deep in the ground. Note that unlined Pond 73 eventually hydrated during onset of heavy summer rains in 2018 because it has a deeper pond bottom than the other unlined ponds and therefore interacts more frequently with the aquifer.

When heavy rainfall persisted over time, long enough to raise the local groundwater table, then unlined ponds eventually began to fill. However, the process of aquifer recharge typically took weeks or months. During early phases of a recharge period, lined ponds hydrated, bumped up by each rainfall, while unlined ponds did not fill with water until the groundwater level had risen high enough to become exposed within unlined pond basins. When unlined ponds finally became hydrated, then each successive measurable rainfall would raise both unlined and lined ponds synchronously. During extremely wet periods, if heavy rainfall persisted long enough, eventually the local aquifer level would overtop liner levels in lined ponds, and aquifer hydrology became the only driving force for both lined and unlined ponds. During wet periods when water levels overtopped liners, each subsequent significant rain would bump up all lined or unlined study ponds synchronously.

During drying trends, after wet periods when all lined and unlined ponds were hydrated, unlined ponds dried first, while lined ponds typically retained persistent water pools atop liner basins for weeks or months beyond their unlined counterparts (Figure 7).

Three years' worth of rainfall and water level monitoring data from lined/unlined pond pairs clearly show that all lined ponds had water present in basins significantly longer than unlined control ponds in each and every year of this study (2017-2019). Paired t-tests show a statistical difference between each lined and unlined wetland pair in both hydration days and pond level metrics ( $\Pr(T > t) = 0.0000$  at 95% confidence interval).

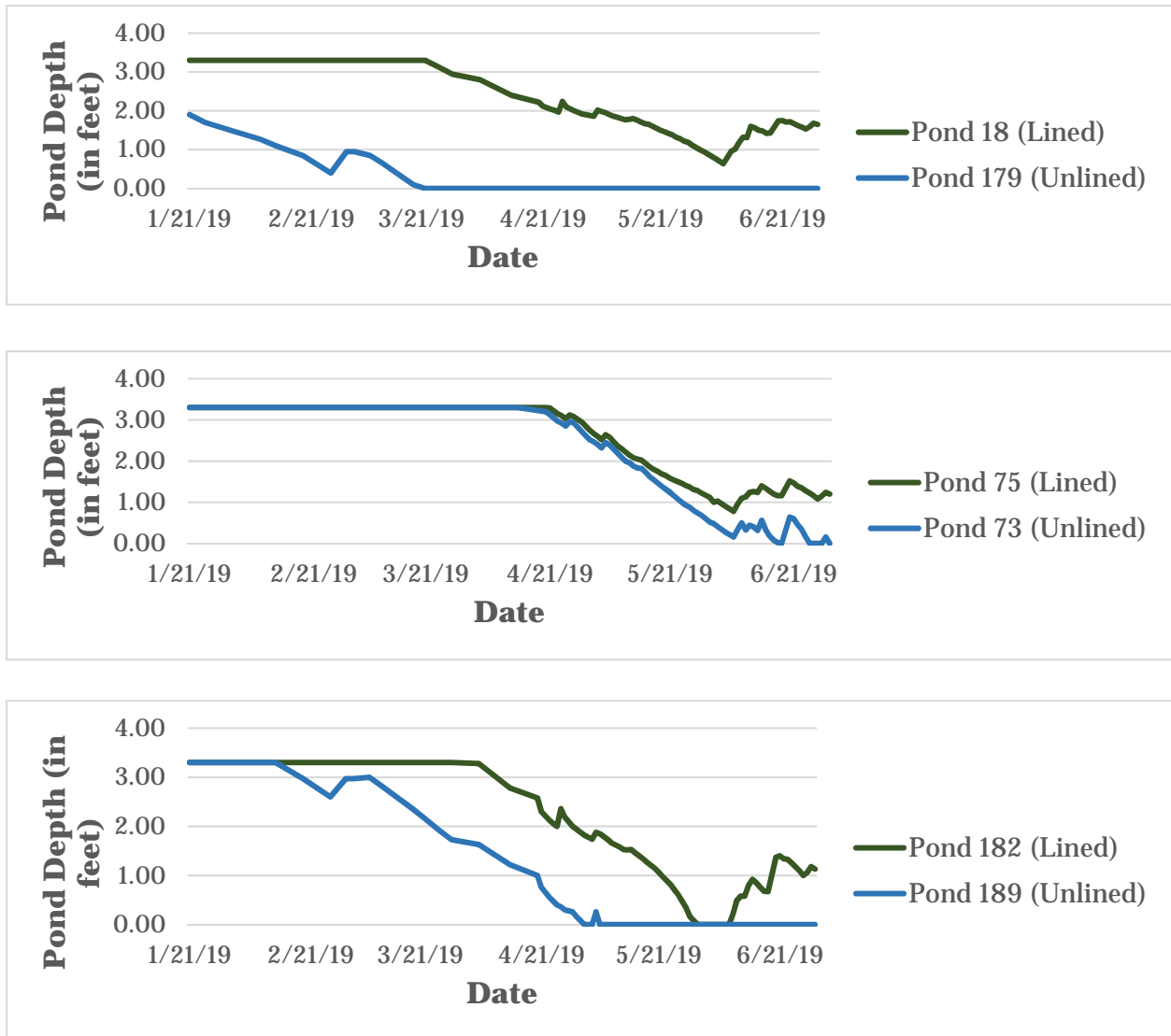


Figure 7. Water levels of lined/unlined pond pairs during a period of decreased rainfall and aquifer drawdown. Unlined wetlands dried sooner than lined wetlands because lined ponds retained persistent pools perched atop liners. Occasional rainfalls (spikes in the graphs) rejuvenated lined ponds even as the aquifer recessed below pond bottoms, whereas the same rains would percolate into the bottoms of unlined ponds. Note that unlined Pond 73 remained hydrated longer than the other unlined ponds because it has a deeper bottom and interacts more frequently with the aquifer.



Two noteworthy observations from the Striped Newt Repatriation Study provide additional information about the effectiveness of liners.

In 2012, as part of developing a conservation strategy for the imperiled striped newt, we tested whether a dry unlined pond would respond to a supplemental water augmentation in the Munson Sandhills. We delivered 5000 gallons of supplemental water into the dried basin of Pond 1 (approximately 1 mile west of our current study area) and observed water levels. Water rose during the half-hour hydration event, then spent the next five hours percolating completely into the pond bottom until dry (Means et al. 2012). Had a liner been in place under the pond, all water would have perched and remained pooled in the basin indefinitely.

In Spring 2017, water levels of lined ponds were lowering to near dryness, while unlined ponds had been dry for months. On 24 March, 2017, we acted to deliberately avoid drying of Pond 18 in order to save existing aquatic striped newts and preserve their chances to breed successfully that given year. We delivered 4000 gallons of supplemental water into Pond 18. As water rushed from a tank through a hose into the wetland, water level of Pond 18 synchronously rose by 0.7 feet while water flowed into the pond, and the wetland diameter doubled. Supplemental water level rose to near liner capacity. This wetland augmentation event provided Pond 18 with enough water to resist drying during the remainder of a dry spring until the summer monsoonal rains began. Shortly after Pond 18 augmentation, the other two lined ponds (75 and 182) went dry. Had we attempted augmentation in an unlined wetland, we would have lost all supplemental water rapidly to percolation as was seen in Figure 5, and as we previously demonstrated in Means et al. (2012).

We recognize that this study lacks baseline hydrological data from prior to the installation of liners. Even though we lack hydrology/rainfall data from our six study ponds prior to the installation of liners, we believe the three replications of paired lined/unlined wetlands provide clear evidence that liners increase pond hydroperiods in a landscape that lacks confining layers underneath pond bottoms. Regardless, any future similar studies should include baseline monitoring, as it would likely provide additional scientific support.

In summary, when our study region's local groundwater aquifer was recessed deeply underground due to climatic dryness or other factors, unlined ponds typically remained dry, while lined ponds typically would retain persistent pond pools perched atop lined pond centers. Unlined ponds required much more rainfall to become hydrated. Unlined ponds did not respond to single rainfall events but depended on a rise in the underground aquifer level in order to hydrate. However, because of the presence of the impermeable liners, lined ponds responded instantly to single moderate/heavy rainfalls, and they consequently remained hydrated for much longer than unlined ponds and for nearly the entire sampling period. Lined ponds eventually would dry only during extremely hot and dry periods.

## **Amphibian Community Assessment**

We conducted a total of 14 dipnet surveys in hydrated wetlands during the project period and we conducted nine frog call surveys during the project period (three each year). Data for striped newts are not reported as they are affected by our repatriation efforts, and likely are only in the wetlands in which they have been repatriated. Repatriation activities can be variable from pond to pond, and often are dependent on several other uncontrolled variables. When assessing and comparing amphibian communities between wetlands we note two factors of great importance: overall species composition (richness) and recruitment success frequency (i.e. frequency of breeding events that results in larval metamorphosis).

Observed amphibian species richness summarized over three years was similar at all three liner ponds, and at two out of three lined/unlined pond pairs (Table 1). Pond 179 had significantly lower species richness (four species) than it's paired, lined wetland (Pond 18) and the other wetlands in this study. This was likely due to it having the shortest hydroperiod of all six study ponds (Table 2). Also of note, Pond 189 had a very short hydroperiod but had higher species richness. However, species documented for Pond 189 largely occurred during 2019 sampling efforts when the pond basins of Pond 189, it's paired wetland Pond 182, and other nearby wetlands were combined into one large wetland complex. Were it not for high wintertime water levels and rainfall in 2019, only southern cricket frogs (Pond 179) and oak toads (Pond 189) would have been documented at these two unlined wetlands during the entire three year study period.

**Table 1.** Summary of species composition of all study wetlands for the project period. Data represent all three detection methods combined – dipnet (D), frog call (FC), opportunistic encounters (O).

Species	Lined	Unlined		Lined	Unlined		Lined	Unlined
	Pond 18	Pond 179		Pond 75	Pond 73		Pond 182	Pond 189
<i>Ambystoma talpoideum</i>	D			D	D		D	D
<i>Eurcycea quadridigitata</i>	D							
<i>Notophthalmus viridescens</i>				D			D	
<i>Acris gryllus</i>	FC, D, O			FC, D, O	FC, D, O		FC, D, O	D, O
<i>Anaxyrus quercicus</i>	FC	FC		FC	FC		FC	FC
<i>Hyla femoralis</i>	FC, D			FC, D	FC, D		FC, D	D
<i>Hyla gratiosa</i>	D			D	D		D	D
<i>Psuedacris crucifer</i>				FC	FC			
<i>Pseudacris ocularis</i>				FC	FC		D	
<i>Psuedacris ornata</i>	D	D		D	D		FC, D	D
<i>Rana capito</i>	D, O	D		D, O	D		D, O	D
<i>Rana catesbiana</i>	O			D				
<i>Rana sphenoccephala</i>	FC, D	D		FC, D	FC, D, O		FC, D	FC, D
<b>Total Species</b>	<b>10</b>	<b>4</b>		<b>12</b>	<b>10</b>		<b>10</b>	<b>8</b>

**Table 2.** Hydroperiod chart showing presence (blue) or absence (white) of water during each month of our study period. Presence is only denoted if the wetland remained hydrated for the entire month. Lined ponds held at least some water significantly longer than unlined ponds in all three study pond pairs.

	<b>Lined</b>	<b>Unlined</b>		<b>Lined</b>	<b>Unlined</b>		<b>Lined</b>	<b>Unlined</b>
	Pond 18	Pond 179		Pond 75	Pond 73		Pond 182	Pond 189
Jan-17								
Feb-17								
Mar-17								
Apr-17								
May-17								
Jun-17								
Jan-18								
Feb-18								
Mar-18								
Apr-18								
May-18								
Jun-18								
Jan-19								
Feb-19								
Mar-19								
Apr-19								
May-19								
Jun-19								

Table 2 also corresponds to recruitment success frequency. The lined wetlands stayed hydrated long enough for larvae to metamorphose throughout most winter and summer breeding seasons of this project. Amphibian breeding and recruitment frequency was significantly higher at lined ponds because of the presence of water. Conversely, unlined wetlands that typically lacked water did not frequently support amphibian breeding and recruitment. A noteworthy exception was during the extremely wet winter of 2019. All study ponds filled and major breeding events of gopher frogs and ornate chorus frogs occurred at all six wetlands. However, unlined ponds dried much quicker than lined ponds in the ensuing dry springtime. Many tadpoles did not make it to metamorphosis in unlined ponds due to rapid drying (Figure 8). This is true even at Pond 73, which had the longest hydroperiod of all the unlined wetlands. Pond 73 hydrated and dried seven times during the project period. Frequent interruptions in hydroperiod reduced breeding success at Pond 73.





**Figure 8.** Tadpole die-off at unlined Pond 73. Tadpole die-offs were more frequent at unlined ponds than lined ponds because unlined pond hydroperiods often were not long enough to support full larval development of resident amphibian species.

Species richness of ponds was robust and indicative of healthy amphibian communities of north Florida longleaf pine sandhill ecosystems. However, there were more frequent opportunities for amphibians to breed and breeding events were more successful (i.e. metamorphosis occurred) in lined ponds when compared to their unlined counterparts because of hydroperiod extensions created by presence of liners.

We note that liners did not produce any observed deleterious effects to amphibian communities during our study. We also note that, at any unspecified time in the future, if land managers desire to restore pond hydroperiods of lined wetlands back to pre-liner conditions, it would be simple to do so by perforating the liner several times with a tool such as a soil auger.

## CONCLUSIONS

Our results suggest that liners increase pond hydroperiods, provide increased opportunities for resident amphibians to breed in a drought-stricken landscape and have not had any observed deleterious effects to pond fauna. Additionally, liners have been very beneficial to striped newt repatriation efforts and are believed to be responsible for almost all repatriation success thus far (Means et al. 2017). We conclude that liners are operating favorably and in line with our current conservation and management needs. Although we lack sampling data from prior to liner installations, we believe hydroperiod extension of lined ponds was caused by the presence rubber liners beneath ponds.

We note that when installing the liners, it was our intent to provide water refugia for developing striped newts that would eventually be released into the ponds. We needed to ensure that released newts would have enough water, and therefore time, to reach metamorphosis in what had been a drought-stricken, aquifer-recessed landscape. Data show that liners have increased hydroperiods of ponds and are performing their intended role of helping striped newts and other amphibian species reproduce. Additionally, liners are providing habitat for species previously undocumented at those wetlands, such as gopher frogs and eastern newts at Pond 182. It was of equal importance that we not create “permanent” wetlands. After three years of collecting hydrological data, the evidence shows we have thus far accomplished both objectives.

With the onset of climate change, hydroperiods will shorten in ephemeral wetlands (IPCC 2007). In the sandhills habitat, climate-induced drought will have negative impacts on ephemeral pond-breeding amphibians. These habitat specialists cannot breed unless the breeding pond hydroperiod is sufficient. While installing liners in ephemeral wetlands on a landscape level is not a practical management tool, this project provides a template for targeted active management practices in instances where drought may have severe and lasting negative impacts. Those activities could include relocation, repatriation, or translocation, and efforts to increase population sizes of imperiled amphibian species expected to be negatively impacted by climate change-induced drought.

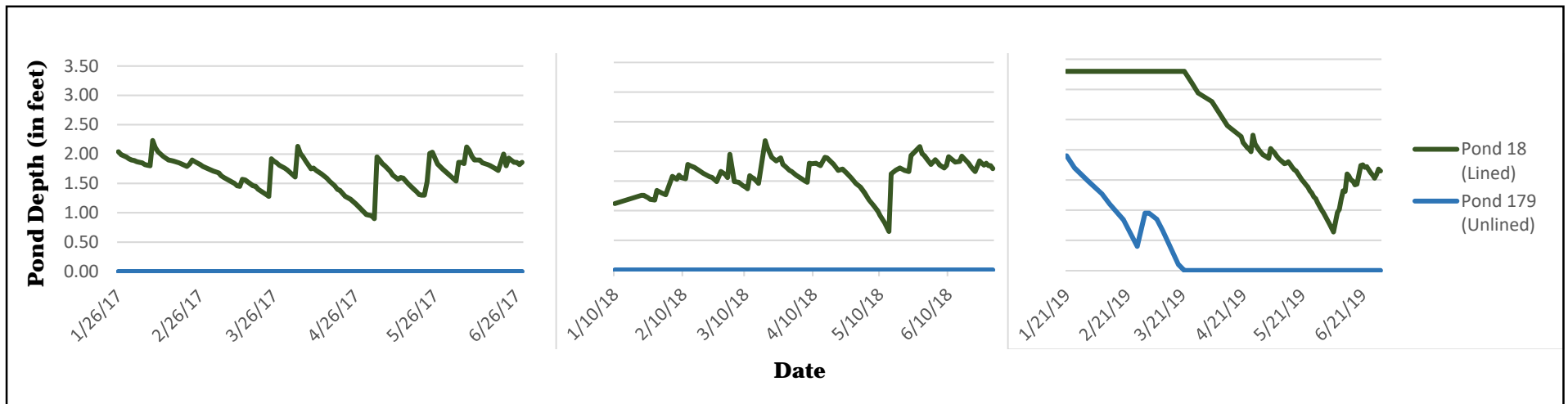
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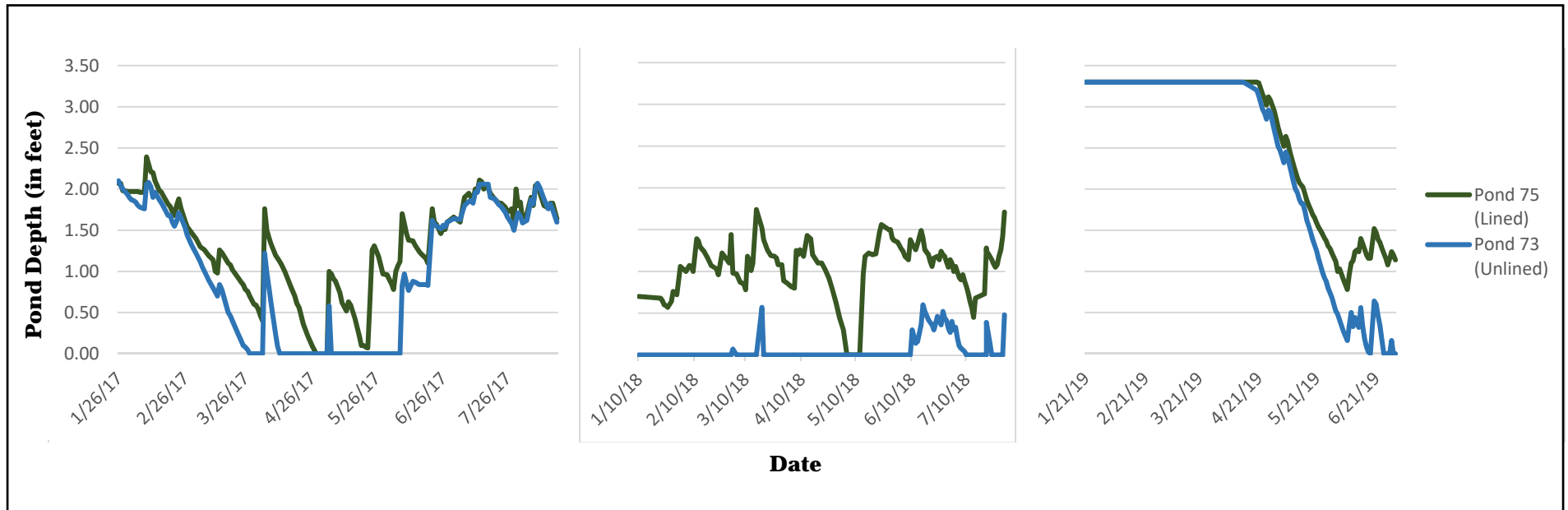
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**APPENDIX A. Hydrological Graph of paired lined and unlined wetlands Ponds 18 and 179.** Pond 18 held water throughout the project period (305 sampling days). Pond 179 was dry for the first two years of this project and held water for 12 sampling days during February and March of 2019.





**APPENDIX B. Hydrological Graph of paired lined and unlined wetlands Ponds 75 and 73.** Pond 75 held water for 295 sampling days while Pond 73 held water for 225 sampling days. Water levels of Pond 73 were constantly lower than that of the lined wetland, Pond 75.



**APPENDIX C. Hydrological Graph of paired lined and unlined wetlands Ponds 182 and 189.** Pond 189 was dry for the first two years of this project. This graph only shows data from 2019, when both wetlands were hydrated for a period.

