

# **AN ANALYSIS OF DISTURBANCE IN BUFFERS SURROUNDING OCCUPIED WATER HOWELLIA (*HOWELLIA AQUATILIS*) PONDS AND UNOCCUPIED PONDS IN MONTANA**

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# AN ANALYSIS OF DISTURBANCE IN BUFFERS SURROUNDING OCCUPIED WATER HOWELLIA (*HOWELLIA AQUATILIS*) PONDS AND UNOCCUPIED PONDS IN MONTANA

## 1.0 INTRODUCTION

Water howellia (*Howellia aquatilis* A. Gray) is an aquatic plant that is endemic to the Pacific Northwest, occurring in California, Oregon, Washington, Idaho, and Montana. This plant occurs in shallow ponds (also called vernal ponds) and old river oxbows. It is a winter annual that germinates in fall when ponds dry, overwinters as seedlings under snow, and following spring precipitation and snowmelt it grows, flowers, and sets seed into late summer. In Montana water howellia is restricted to the Swan River watershed (HUC 4, 17010211). It was first documented in Montana in 1978 (McCune 1982), and by 2016, it has been found in 220 ponds in the state. Surveys conducted at another 86 ponds in the Swan River watershed resulted in not finding water howellia, and these ponds have been term “unoccupied” (also called u-ponds). Unoccupied ponds have potential habitat for water howellia and are deemed unoccupied based on limited observations made between 1987 and 2010. For the purpose of this analysis, it is assumed that these ponds do not have water howellia; however, it is possible that surveys occurred in years where detection was difficult or that colonization in these ponds has since happened.

Since 1994 water howellia has been federally-listed as threatened under the Endangered Species Act. Federal and State land managers in Montana have enacted various protections, namely by reducing or eliminating actions within the forested buffers around ponds. On the Flathead National Forest (FNF) where a majority of the occupied ponds occur, the Conservation Strategy - *Howellia aquatilis* was created in 1994 and revised in 1997 (United States Forest Service (USFS) 1994 and 1997; hereafter referred to as the Conservation Strategy). This Conservation Strategy was to ensure the long-term viability of water howellia on USFS lands in Montana. This document recognized that timber harvesting, grazing, or road construction activities around an occupied pond could be a threat to water howellia by potentially altering pond hydrology and/or associated vegetation. To provide long-term protection the Conservation Strategy prescribed protections for both occupied and unoccupied (potential) water howellia habitat on the FNF. One of the protection prescriptions created a minimum 300-foot buffer of intact forest around “currently” undisturbed ponds and previously disturbed occupied ponds. The buffer’s purpose is to maintain the structural and floristic diversity of the mid- to late-seral forests as well as the vegetative, hydrologic, and geomorphologic conditions that determine the natural seasonal inundation and drying patterns of the vernal pond habitat. In some cases where ponds share a buffer, the minimum 300-foot width could be less. The Conservation Strategy states that ground-disturbing activities within the buffer of occupied and unoccupied ponds should be avoided, but recognized that some forms of management may be necessary to maintain the integrity of the buffer. Thus, timber harvests are not necessarily prohibited within these buffers, as was implied in the Five-Year Review: Summary and Evaluation of Water Howellia (USFWS 2013).

The effectiveness of 300-foot buffers around occupied and suitable but unoccupied ponds in Montana has not been scientifically studied. Further, no study has examined the effect of disturbed and undisturbed forest buffers on the presence/absence of water howellia. An

exploratory analysis that looks at the persistence of water howellia from 1978 to 2014 in occupied and unoccupied ponds with disturbed and undisturbed forested buffers can be done using existing data-sets. Using existing data-sets, we examined the persistence of water howellia in relation to past management activities (forest stand treatments, fire, grazing, and roads) adjacent to its habitat. While a direct cause and effect relationship between buffer conditions and water howellia population trends cannot be determined, general inferences can be made regarding the persistence of the species in disturbed and undisturbed settings.

## **2.0 METHODS**

The Montana Natural Heritage Program (MTNHP) maintains the database for water howellia occurrences in Montana. Each water howellia occurrence is mapped at the pond level, numbered, and tracked as an Element Occurrence (EO; also called an SO (Species Occurrence) by the MTNHP. In 2016, the Geographic Information System (GIS) data for all 220 EO ponds (occupied by water howellia) were visually inspected to determine if mapping was spatially accurate. Ponds that did not accurately represent conditions seen in the imagery (ArcGIS Map Service *World Imagery*, 2013) were manually re-digitized at a scale between 1: 2,000 and 1: 4,000. The 220 occupied and 86 unoccupied ponds were buffered by 300 feet (91.44 meters) using the ArcGIS buffer tool. Of these ponds, 137 occupied and 37 unoccupied ponds share a buffer with at least one other pond. Analysis of the entire buffer was conducted independently for each pond without regard for overlap, even though, overlapping buffers are common.

Disturbance(s) within the buffer around each occupied and unoccupied pond was determined using the stand treatment and 2013 transportation GIS layers obtained from the FNF, the 2010 historic fire perimeter GIS layer developed by the Montana Natural Heritage Ecology Program (MTNHP 2010), and grazing studies conducted by the USFS. The 2015 Montana Cadastral Framework parcel data provided grazing allotment boundaries with no information on grazing use; therefore, this data was not used in the analysis. The stand treatment GIS layer provided data spanning from the early 1900s to 2014 using 2013 imagery. For this project, the analysis only included stand treatments that occurred in occupied and unoccupied pond buffers from 1978 (the first year that water howellia was found in Montana) through 2014. The disturbance type(s), area(s), and proportion in the pond buffer was calculated by intersecting the 300-foot buffer with the stand treatment, transportation, and fire data layers using the ArcGIS Intersect geoprocessing tool. All areas were calculated in acre and hectare. A *two-sample proportions* statistical test was performed to test the null hypothesis of no difference in the proportion of positive water howellia observations in pond buffers with and without stand treatments or roads. This analysis was applied to two data-sets: pooled occupied and unoccupied ponds and only occupied ponds.

### **2.1 Water Howellia Surveys and Observation Data**

The FNF, Plum Creek Timber Company, The Nature Conservancy (TNC), Department of Natural Resources and Conservation (DNRC), MTNHP, and other botanists have conducted population surveys and/or quantitative monitoring studies for water howellia since 1978. The FNF developed monitoring studies that annually visited specific ponds from 1988-1997 (6 occupied ponds), 1998-2007 (62-68 occupied ponds), and 1998-2007 (51 unoccupied ponds)

visited in alternating years). The TNC monitored 55 occupied ponds, formerly owned by Plum Creek Timber Company, from 2010-2012. Efforts to survey as many ponds as possible to determine presence/absence were made by the FNF, MTNHP, Plum Creek Timber Company, and other botanists, particularly from 1988 to 2014. The MTNHP’s botany database maintains all observation data on water howellia. Each time that a pond is visited by a knowledgeable person who is purposely searching for water howellia, the data is entered into our database as an ‘observation’. Thus, an ‘observation’ can be positive (i.e., water howellia was found) or negative (i.e., water howellia was not found); an observation can also be thought of as a pond visit. When pond visits occur they happen once during the growing season, but consecutive annual visits have not occurred at any pond from 1978-2014. Microsoft Excel was used to chart the presence and absence by year for each of 220 occupied ponds and 86 unoccupied ponds. The MTNHP’s botany database contains 1,407 annual observations conducted at the 220 water howellia ponds and 348 observations conducted at 70 unoccupied ponds (MTNHP 2017). There are also 16 ponds that are mapped and numbered as unoccupied, but lack the year(s) in which the negative observation(s) was made.

## 2.2 Stand Treatment Disturbance

Stand treatments (also referred to as timber prescriptions) completed from 1978 to 2014, that occurred within the 300-foot buffer around the margin of each occupied and unoccupied pond were used in this analysis. The stand treatment type, year completed, and area of the buffer affected by the harvest prescription were calculated. A visual timeline of timber prescriptions and presence/absence water howellia surveys for each occupied and unoccupied pond was developed in MS Excel.

Initially each pond’s 300-foot wide forested buffer was categorized as ‘treated’ if it contained at least one stand treatment or as ‘untreated’ if it contained no stand treatment from 1978 through 2014. However, it became apparent that these categories had to be adjusted based on the timing of the stand treatment relative to the date of the first or last (negative or positive) observation for water howellia. Criteria were developed to categorize each occupied and unoccupied pond buffer as either ‘stand treated’ or ‘stand untreated’ (**Table 1**).

**Table 1. Criteria used to determine if the pond buffer was untreated or treated for harvest prescriptions.**

Pond Buffer Category	Timing of Stand Treatment Relative to Pond Visit
Untreated Pond Buffer	No stand treatment occurred within the buffer from 1978 to 2014.
Untreated Pond Buffer	All stand treatments in the buffer occurred <u>after</u> the last pond visit; therefore, at the time of the observation the pond’s buffer had no stand treatment.
Treated Pond Buffer	Stand treatments occurred on and/or between two or more pond visits; therefore, at the time of the observation a stand treatment had taken place in the pond’s buffer.

Since many ponds have more than two years of survey visits and many forested buffers have more than two stand treatments during the 1978-2014 timeframe, we separated observations that occurred when the pond buffer was ‘untreated’ versus when it was ‘treated’ with a harvest prescription. This reduced “noise” in the data, and allowed observations (not just ponds) to be

analyzed in the context of whether the buffer had been treated prior to the date of a particular observation.

**Table 2. Criteria used on treated pond buffers to differentiate observations that occurred before or after the first stand treatment.**

Pond Buffer Observation Category	Timing of Stand Treatment Relative to Date of Observation
Untreated Pond Buffer Observation	An observation was considered ‘untreated’ if it preceded the date of the first stand treatment at that particular pond.
Treated Pond Buffer Observation	An observation was considered ‘treated’ if it occurred in the same year or after the first stand treatment at that particular pond.

The persistence of water howellia in ponds surrounded by treated and untreated pond buffers was examined using two data-sets: a) observation data pooled for 306 occupied and unoccupied ponds, and b) observation data for only 220 occupied ponds. The pooled data-set includes known and potential habitats for water howellia, which are both managed by the FNF in accordance with the Conservation Strategy (USFS 1997). The pooled data-set increased the sample size. The pooled data-set allowed inferences to be made on stand treatments across all pond types over a larger geography, though occupied and unoccupied ponds are often nearby to one another. Botanists recognize that unoccupied ponds vary in their quality of the perceived habitat for water howellia. Thus, to make inferences on the persistence of water howellia it is also necessary to examine only the data-set of occupied ponds where water howellia is known to grow. Examining the “occupied pond” data-set removed some variation in the pond sampling that made some data interpretation difficult.

The number of observations positive and negative for water howellia and the proportion of positive observations were calculated for the pooled and the occupied pond data-sets. A *two-sample proportions* statistical test was used to test the null hypothesis of no difference in the presence of water howellia between ponds with treated and untreated buffers. This statistical test was applied to both the pooled and occupied pond buffer data-sets.

The trend in positive water howellia observations was examined across years for the pooled and occupied pond buffer data-sets. In both data-sets the proportion of positive observations were only charted if at least 10 ponds were visited in a particular year. Eliminating years in which observations were made on less than 10 ponds reduced the noise created by a year’s low sample size and helped detect a visual trend.

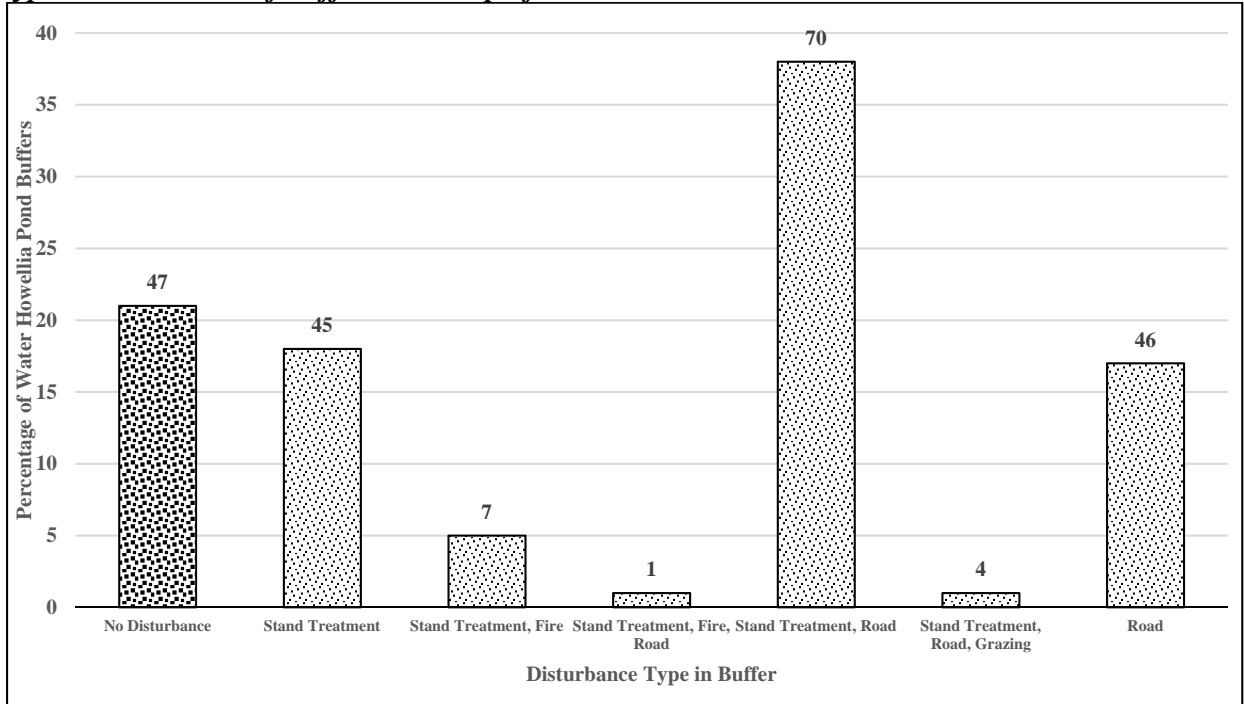
### 3.0 RESULTS AND DISCUSSION

Surveys for water howellia have occurred at 220 occupied ponds and 86 unoccupied ponds from 1978-2014. Characteristics on pond/buffer ownership, pond/buffer size, disturbance type(s) found in buffers, first/last year pond was surveyed, and the first/last observation of water howellia were compiled (**Tables A-1 and A-2 in Appendix A**). To put the persistence of water howellia into context, the array of disturbance types that occurred in each occupied and unoccupied pond buffer from 1978 to 2014 was evaluated. Manmade disturbances in pond buffers included stand treatments, roads, and grazing, while natural disturbances in buffers included fire. Approximately one-fifth of occupied pond buffers and one-third of unoccupied pond buffers lack any type of disturbance (i.e. are undisturbed) between 1978 and 2014 (**Table 3; Figures 1-2**). Therefore the majority of occupied water howellia pond buffers have been disturbed with stand treatment(s), fire, road development, and/or livestock grazing during this time period (**Table 3; Figure 1**). Likewise, the majority of unoccupied pond buffers have been disturbed with stand treatment(s) and/or road development between 1978 to 2014 (**Table 3; Figure 2**).

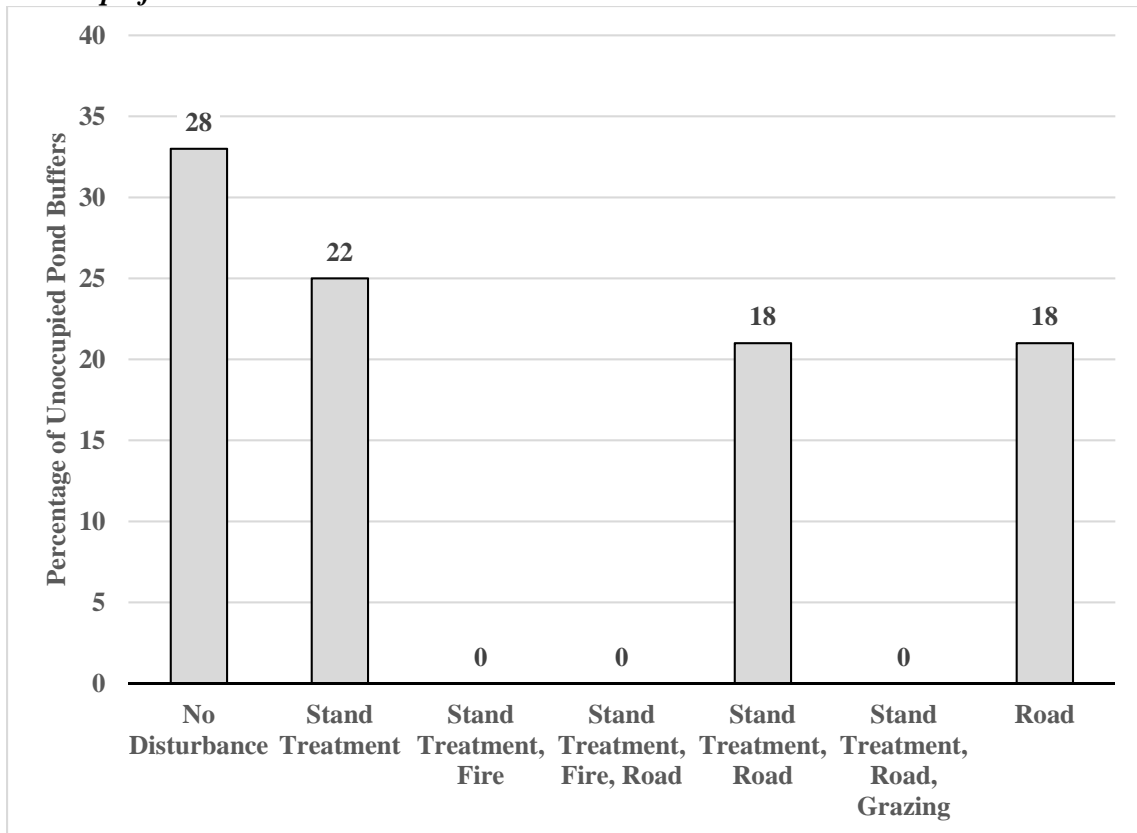
**Table 3. Disturbance types found in occupied water howellia and unoccupied pond buffers.**

<b>Disturbance Type in Buffer</b>	<b>Number (Percentage) of Occupied Water Howellia Pond Buffers</b>	<b>Number (Percentage) of Unoccupied Pond Buffers</b>
No Disturbances	47 (21%)	28 (33%)
Stand Treatment	45 (18%)	22 (25%)
Stand Treatment, Fire	7 (5%)	0
Stand Treatment, Fire, Road	1 (1%)	0
Stand Treatment, Road	70 (38%)	18 (21%)
Stand Treatment, Road, Grazing	4 (1%)	0
Road	46 (17%)	18 (21%)
<b>Total Number (Percent) of Ponds</b>	<b>220 (100%)</b>	<b>86 (100%)</b>

**Figure 1. Percentage and number of occupied water howellia pond buffers by disturbance type. The number of buffers is on top of each bar.**



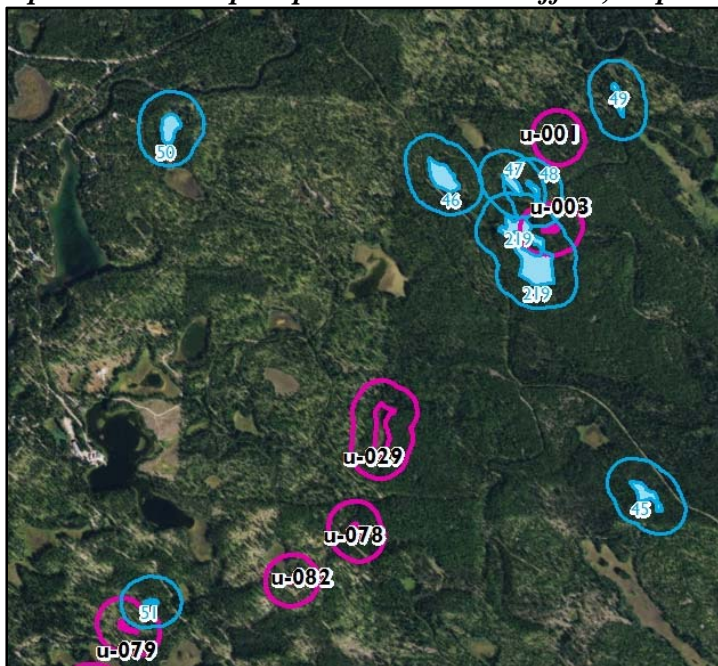
**Figure 2. Percentage of unoccupied pond buffers by disturbance type. The number of buffers is on top of each bar.**





For each pond buffer, the type of disturbance, its severity and timing of impact is highly variable. Across the landscape the buffers that surround 220 occupied and 86 unoccupied ponds reflect the range of variation in past land management found in the Swan River watershed (**Figure 3**). Collectively the majority (79%) of occupied water howellia pond buffers contain at least one stand treatment and/or road of which a few also have had fire or livestock grazing. Likewise, the majority (67%) of unoccupied pond buffers contain at least one stand treatment and/or road, but none have been impacted by fire or livestock grazing. The minority of pond buffers lack disturbance (i.e., stand treatment, fire, road, and/or livestock grazing), regardless of whether the buffer surrounds an occupied water howellia pond or unoccupied pond.

**Figure 3.** An aerial view of selected ponds illustrating the variation in disturbance types, or lack thereof, in buffers adjacent to ponds. Blue polygons and lines represent occupied water howellia ponds and their buffers, respectively. Pink open polygons surrounded by pink lines represent unoccupied ponds and their buffers, respectively.

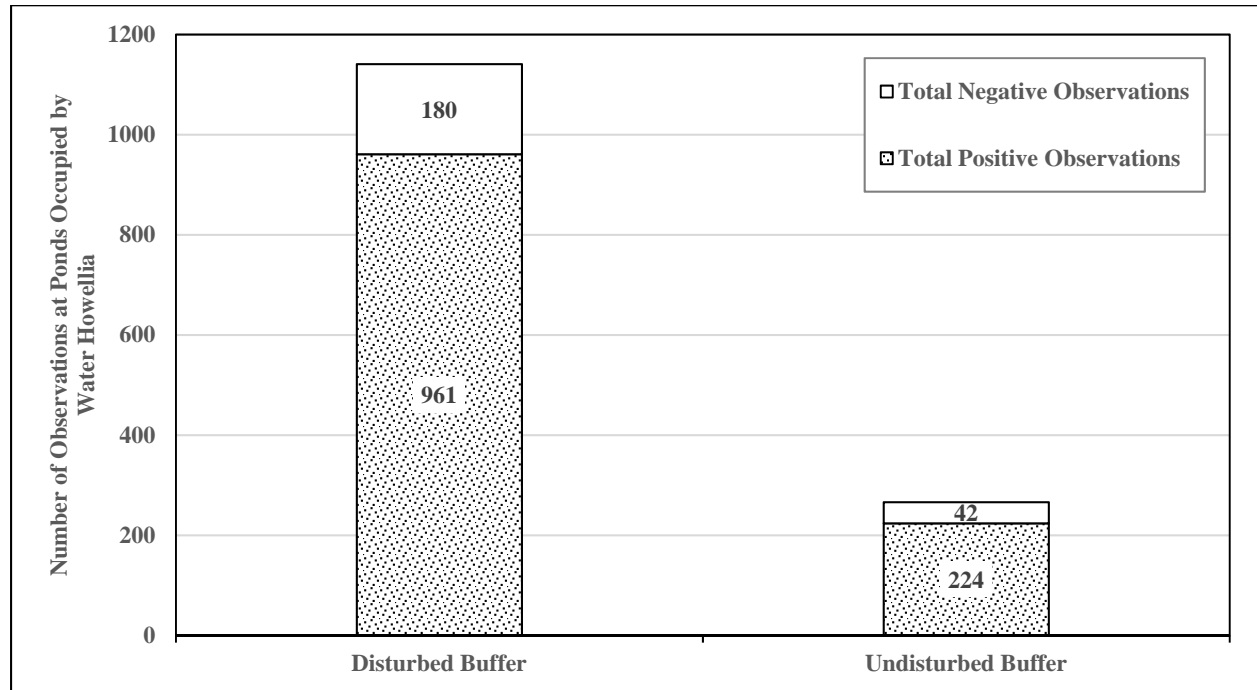


The percentage of positive water howellia observations found in ponds with disturbed and undisturbed buffers was evaluated. For the 220 occupied water howellia ponds, 1,407 pond visits (observations) were made between 1978 and 2014. The 47 occupied ponds with an undisturbed buffer had 42 visits where water howellia was absent and 224 visits where it was present (**Figure 4**). The 173 occupied ponds with a disturbed buffer had 180 visits where water howellia was absent and 961 visits where it was present (**Figure 4**). Thus, 84% of observations were positive for water howellia in ponds with either disturbed or undisturbed buffers (**Figure 4**). Absence in all cases is likely a result of inadequate pond drying, and resultant depressed seed germination, in the years prior to “absent” observations, as indicated by the long-term monitoring studies (Shelly, Pipp, and Mantas manuscript in progress). For the 86 unoccupied ponds, 146 visits were at 26 ponds with an undisturbed buffer, 202 visits were at 44 ponds with a disturbed buffer, and for 16 ponds the year of visitation between 1978 and 2014 is unknown. Based on these 348 observations where water howellia was searched for and not found (most



surveyed over extended time periods), these 86 ponds were databased as unoccupied. It can be inferred that under the existing levels of disturbance found in occupied pond buffers, the persistence of water howellia has not been limited by buffer disturbance(s). Across the timeline from 1978 to 2014 no pattern related to disturbance was found in the presence or absence of water howellia (**Table A-4** in **Appendix A**).

**Figure 4.** *The number of presence or absence observations at occupied water howellia ponds with or without disturbed buffers (stand treatment, road, livestock grazing, and/or fire) from 1978-2014.*



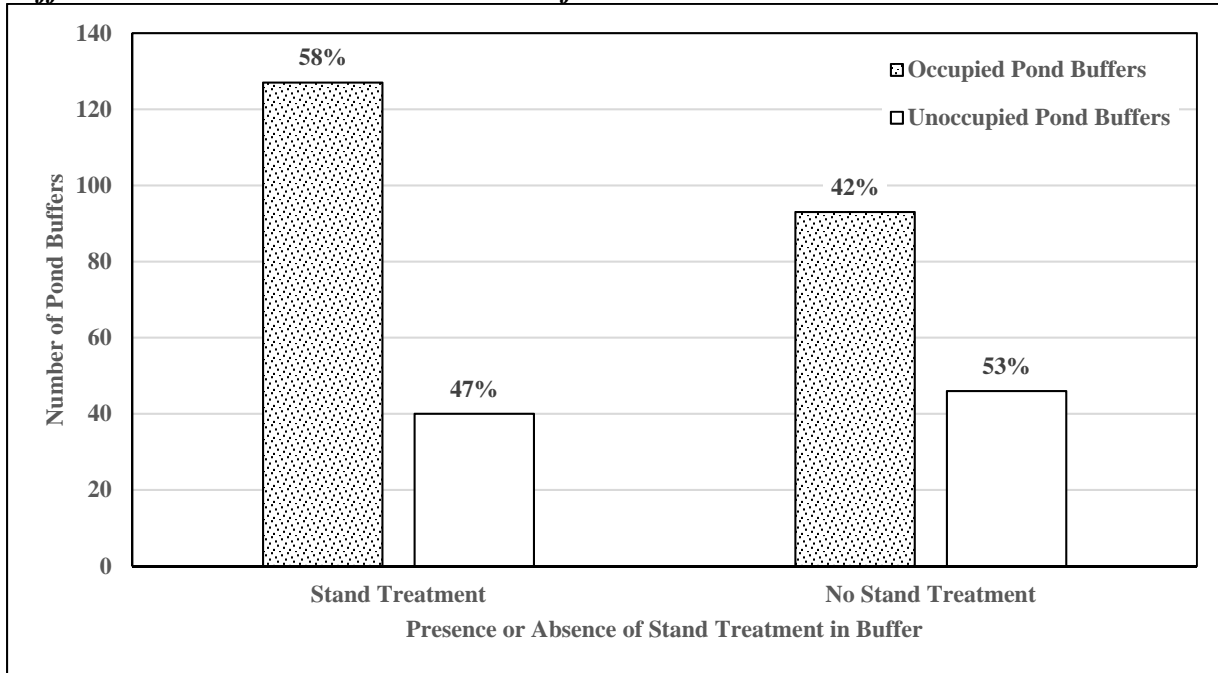
### 3.1 Stand Treatment Disturbance

From 1978 to 2014, 212 stand treatments were implemented in the 300-foot buffer surrounding 127 water howellia occupied ponds (**Figure 5; Table 4; Tables A-3 and A-4** in **Appendix A**). During the same period, 81 stand treatments were implemented in the 300-foot buffer surrounding 40 unoccupied ponds (**Figure 5; Table 4**). Stand treatments consisted of 17 different harvest prescriptions (**Table 4**). The amount of buffer disturbed by a stand treatment was highly variable across pond buffers and years. For any particular stand treatment in a given year the amount of buffer disturbed could range from less than an acre to the entire buffer. In most years, a single stand treatment type was applied to a particular pond buffer. At 14 pond buffers two or three stand treatment types were applied in the same year during the 1978-2014 period. The remaining 93 water howellia occupied pond buffers and 46 unoccupied pond buffers lacked stand treatments during this period (**Table 3; Figure 5**).

Given that stand treatments have occurred in occupied water howellia pond buffers warrants the need to evaluate their effect on water howellia’s persistence from 1978-2014. The timing of when stand treatments were implemented in buffers relative to our awareness of whether or not the pond contained water howellia depends upon the survey effort in a particular year. Efforts to

survey ponds for water howellia were greatest between 1987-1991, 1997-2007, and 2010-2012. Based on the timing of the stand treatment(s) relative to the pond visit, observations were categorized as occurring in a pond with a stand treated or untreated buffer (**Table 5**).

**Figure 5. The number and percentage of water howellia occupied and unoccupied pond buffers with and without stand treatments from 1978 to 2014.**



**Table 4. The type and number of stand treatment prescriptions and fire events found in occupied and unoccupied pond buffers from 1978-2014.**

Stand Treatment or Fire in Buffer	Number of Buffers	
	Occupied Ponds	Unoccupied Ponds
Commercial Thin	19	12
Group Selection Cut	3	2
Improvement Cut	4	2
Liberation Cut	4	1
Overstory Removal Cut (from advanced regeneration)	8	1
Patch Clearcut	0	1
Salvage Cut (intermediate treatment, not regeneration)	39	19
Sanitation Cut	0	1
Seed-tree Final Cut	12	10
Seed-tree Preparatory Cut	26	1
Seed-tree Seed Cut (with and without leave trees)	54	18
Shelterwood Establishment Cut (with or without leave trees)	1	3
Shelterwood Removal Cut	0	4
Single Tree Selection Cut	1	0
Stand Clearcut	37	2
Stand Clearcut (w/ leave trees)	4	2
Two-aged Seed-tree Seed and Removal Cut (w/reserve)	0	2
Fire (not a stand treatment type)	8	0
<b>Total Stand Treatment Prescriptions / Fire Events</b>	<b>212 / 8</b>	<b>81 / 0</b>

**Table 5. Number of occupied and unoccupied pond buffers that are treated with at least one stand treatment or that are untreated.**

Pond Buffer Category	Occupied Ponds (number)	Unoccupied Ponds (number)
Treated Buffer-Precedes: All stand treatments in buffer precede first observation (negative or positive) for water howellia.	70	20
Treated Buffer-Between: Stand treatment(s) in buffer occurs on or between observations (negative or positive) for water howellia.	57	11
Untreated Buffer: No stand treatment occurs in the buffer at the time an observation for water howellia was made.	93	39
<b>Total Number of Ponds</b>	<b>220</b>	<b>70<sup>1</sup></b>

<sup>1</sup> 16 unoccupied ponds were removed from the data-set because the exact year in which water howellia was searched for is unknown.

The proportion of positive water howellia observations in ponds where buffers were stand treated and untreated was statistically tested for the pooled (occupied plus unoccupied) and occupied pond data-sets (**Table 6**). When pooled, ponds with stand treated buffers had a higher percentage (70%) of positive water howellia observations than did untreated buffers (65%) (**Table 6**). The observed proportion of positive water howellia observations was significantly different between pooled treated and untreated pond buffers (X-squared = 5.8947, df = 1, p-value = 0.01519; 95% confidence interval ranged from 0.01049 to 0.10038). Although the difference was statistically significant, it was not biologically a large difference. The difference could possibly be attributed to the characteristics of pond visited. Occupied ponds have the necessary habitat requirements for water howellia while unoccupied ponds vary in their quality of what is perceived to be habitat for this aquatic plant. Sampling effort (number of observations per pond) was higher on average for occupied ponds (6.3 visits per pond) than for unoccupied ponds (4.9 visit per pond) from 1978 to 2014, and this may also influence our results. The statistical significance could reflect a notion that stand treatments around ponds may increase water howellia populations by providing more light, warmer air and water temperatures, and more late-season drying that could be beneficial to seed germination. On the Joint Base Lewis-McChord Military Base in Washington, water howellia ponds were historically surrounded by prairie vegetation, but under years of fire suppression, the surrounding vegetation is now composed of Douglas-fir forests (Gilbert personal communication). On this military base water howellia occurs in the portion of pond that receives the most light and the least shade; it is thought that removing surrounding vegetation would increase the distribution of water howellia in these ponds (Gilbert personal communication). In the Swan River watershed, populations have persisted in ponds where the forest canopy has been opened to varying degrees, indicating that increased light in the pond environments has not adversely affected the habitat.

The proportion of positive water howellia observations in ponds where buffers were stand treated and untreated was statistically tested for the occupied pond data-set (**Table 6**). Occupied ponds with treated buffers had a lower percentage (83%) of positive water howellia observations than did untreated buffers (86%) (**Table 6**). This difference was not significantly different (X-squared = 1.8511, df = 1, p-value = 0.1737; 95% confidence interval ranged from -0.06736 to

0.01143). In contrast to the pooled data-set, occupied ponds with treated buffers had 3% less positive observations than occupied ponds with untreated buffers; although, biologically this difference is small. Again, sampling effort may influence these results. It is likely that a balancing act among suitable habitat, sufficient water in the pond from early to mid-season, and sufficient drying of the pond into late-season has a greater influence on the annual presence or absence of water howellia than does stand treatment. Water howellia populations appear to be persisting with a wide-range of stand treatment types and amount of disturbance. The analysis suggests that positive water howellia observations are not limited by the existing array of stand treatments from 1978-2014.

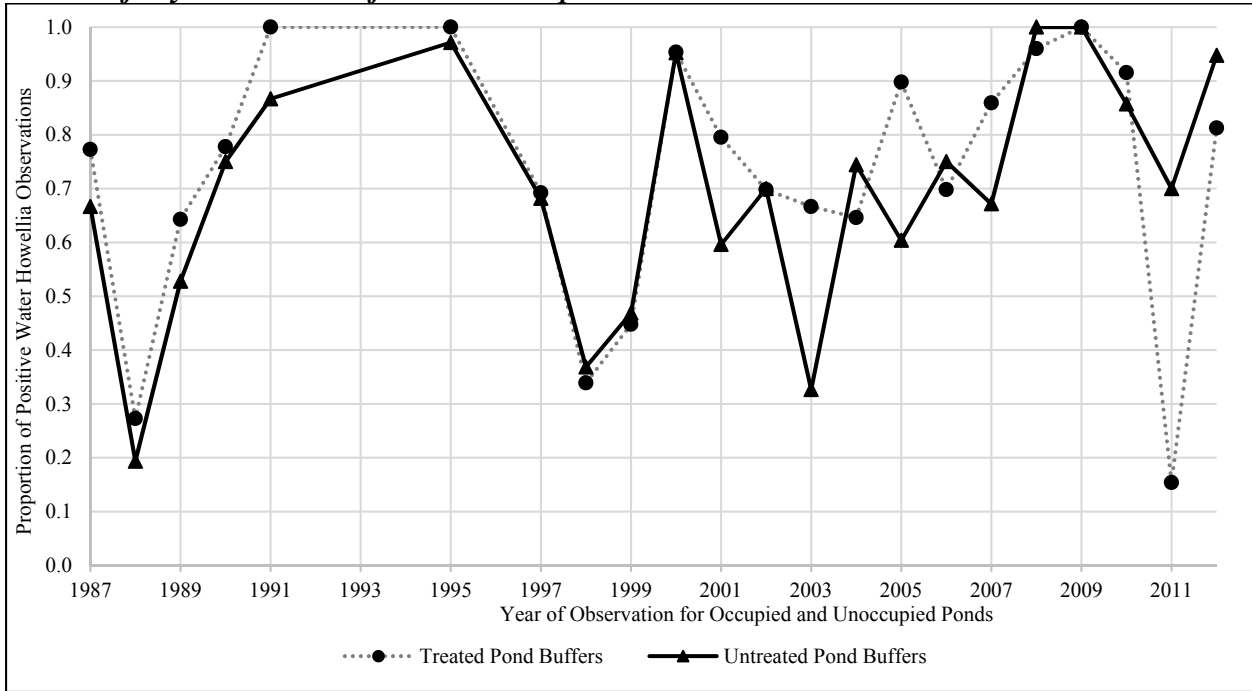
**Table 6. The number and proportion of total and positive observations for water howellia by treated and untreated pond buffers and occupied and unoccupied ponds.**

Group	Number of Yearly Observations		
	All Observations (negative and positive)	Positive Observations for water howellia	Proportion of Observations Positive for Water Howellia
<b>TREATED Buffers</b>	<b>900</b>	<b>632</b>	<b>0.70*</b>
Occupied Pond observations	762	632	0.83
Unoccupied Pond observations	138	0	
<b>UNTREATED Buffers</b>	<b>855</b>	<b>553</b>	<b>0.65*</b>
Occupied Pond observations	645	553	0.86
Unoccupied Pond observations	208	0	

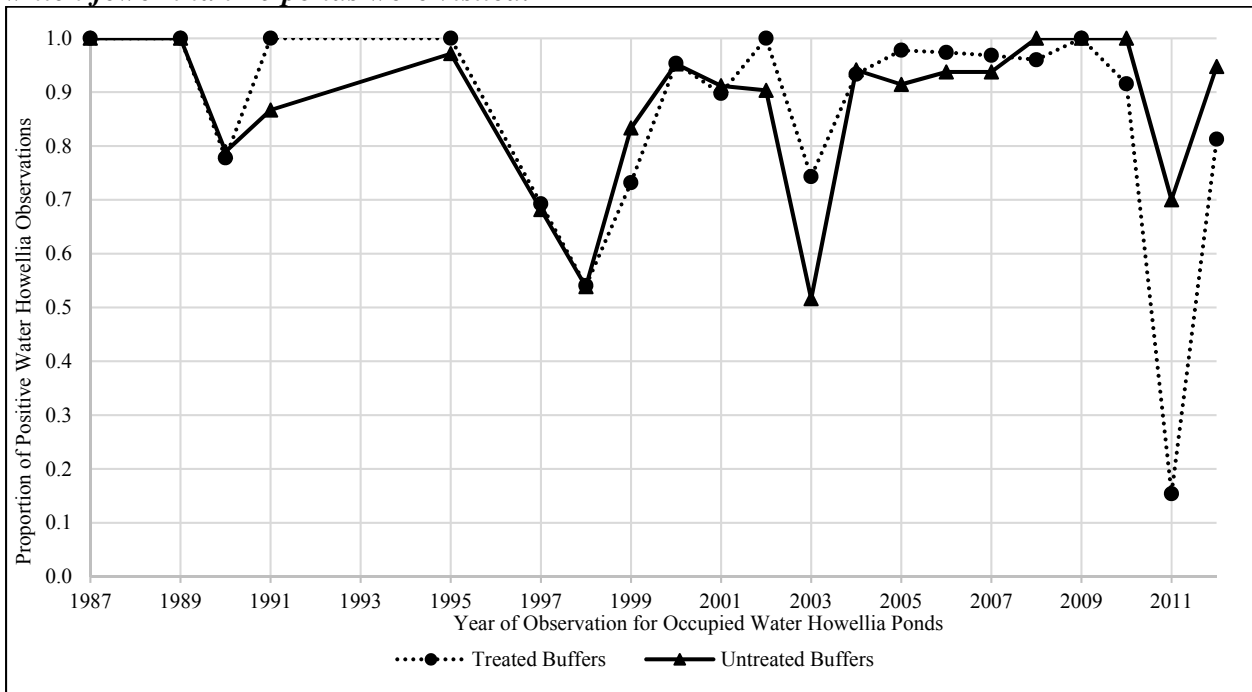
\* The proportion of positive observations for water howellia was significantly different between pooled treated and pooled untreated pond buffers.

The trend in positive water howellia observations was examined across years for the pooled data-set of occupied and unoccupied pond buffers (**Figure 6**) and for the occupied pond buffers (**Figure 7**). For both data-sets the proportion of positive observations was only charted for the years in which observations were made for at least 10 ponds. Eliminating the years in which observations were made on less than 10 ponds reduced the noise caused by a low sampling effort and improved the ability to find a trend across a 36-year timeline. For the pooled data-set showed the trend in the proportion of positive water howellia observations from treated and untreated buffers nearly mirrored each other (**Figure 6**). A similar trend in the proportion of positive water howellia observations was observed between treated and untreated buffers in the occupied pond data-set (**Figure 7**). These trends are an indication that the existing stand treatments in buffers may have had little influence on the presence of water howellia in the ponds. Trends in both data-sets could be influenced by many factors, including population size, survey effort, geography, land management, quality of unoccupied pond habitat, and climate, preventing a direct cause and effect determination (**Figures 6 and 7**).

**Figure 6.** *The proportion of positive water howellia observations found in selected occupied and unoccupied ponds with treated and untreated pond buffers. Observation data was removed for years in which fewer than 10 ponds were visited.*



**Figure 7.** *The proportion of positive water howellia observations found in selected occupied ponds with treated and untreated pond buffers. Observation data was removed for years in which fewer than 10 ponds were visited.*



The biggest deviations in positive water howellia observations at treated and untreated pond buffers occurred in 2003 and 2011, in both the pooled and occupied data-sets (**Figure 6** and **7**). From 1998-2007, 62-68 ponds were monitored annually, of which most occur on USFS managed land and approximately 21% had untreated pond buffers. From 2010-2012, 55 ponds formerly owned by the Plum Creek Timber Company were monitored annually, of which 53 pond buffers contained at least one stand treatment and 2 were untreated. Given that in both monitoring studies the majority of ponds had treated buffers is an indication that the dip in positive water howellia observations in 2003 and 2011 is likely attributed to other factors. The 2003 and 2011 declines at ponds with treated and untreated buffers likely reflects precipitation and temperature patterns that negatively influenced germination and growth in the preceding year. The lower proportion of positive water howellia observations seen in 2003 and in 2011 were each preceded by a wetter 2002 and 2010 year. A wetter and/or cooler summer causes inadequate pond drying, which results in reduced fall seed germination and smaller population sizes the following summer. Based on this and other monitoring study analyses (Shelly, Pipp, and Mantas manuscript in progress) annual weather patterns had more influence on yearly water howellia population levels than impacts from stand treatments during 1978-2014 (**Table 6**; **Figures 6** and **7**). Both the extent and timing of pond drying both influence seed germination. Good germination conditions are only met if enough pond drying happens in time for the seeds to be exposed to colder temperatures in the early fall.

In conclusion, this exploratory analysis of positive water howellia observations in ponds with stand treated and untreated buffers indicates that water howellia has been persisting under the existing, yet constantly dynamic forest structure in the Swan Valley. Although stand treatments have occurred within occupied pond buffers, best management practices, guidelines in the Conservation Strategy, and other management tools have resulted in minimizing negative impacts to water howellia populations on the Flathead National Forest since the mid-1990s. The Conservation Strategy stressed that intact forest buffers are important to maintain the vegetative, geomorphic, and hydrologic functions of pond habitat. Based on this analysis, it seems that the existing array of stand treatments has maintained these functions, such that water howellia has persisted with no downward trends detected. However, the persistence of water howellia is largely dependent upon a balance of adequate precipitation and pond drying on an annual basis. Any downward trends in the snowpack (and subsequent pond recharge in the spring) may be a stronger influence on long-term population trends than pond buffer conditions within the Swan Valley watershed.

### **3.2 Fire Disturbance**

The Crazy Horse fire is the only large documented fire that has occurred at lower elevations in the Swan River watershed since 1978. This was a stand-replacing fire that burned in 2003 and started by natural ignition (Robinson 2017). It burned the entire buffer surrounding eight water howellia occupied ponds (**Table 3**). To examine persistence at these ponds, the observation records were examined.

- At EOs 136-139 observations found water howellia to be present in 2004, the year after the fire, at all sites. For EOs 136 and 137 pond visits after 2004 have not been made. At EO 138 the last pond visit in 2010 found water howellia to be absent. At EO 139 the last

pond visit in 2012 found water howellia to be present in 2012.

- At EOs 173-176 post-fire observations were not made until 2008, at which time water howellia was present at all four sites. The last visits to EOs 173-176 occurred in 2015, and again water howellia was present (in low to moderate abundances) at all four sites. At EOs 173 and 175 ponds were dry, water howellia plants shriveled, and few seeds were likely produced. The 2015 surveys found that natural forest regeneration in all four pond buffers appeared healthy and productive.

In conclusion, fire in the Swan River watershed has been a relatively rare occurrence when compared to other regions of Montana. Fires, especially stand-replacing, could negatively impact water howellia in the short term by drying ponds, burning water howellia plants (and seeds), and burning forest vegetation around the ponds. Under typical climatic conditions, water howellia plants should be more resilient to forest fires because of its aquatic habit. However, the Crazy Horse fire of 2003 demonstrated that stand-replacing fires can burn entire buffers and the logs within the pond. Based on the last known observations water howellia plants were seen at seven of these eight ponds affected by this fire. Vegetation within the pond and buffer appear to have recovered and pond hydrology appears to function. Fire may affect water howellia populations, but without other contributing circumstances that might alter pond hydrology, vegetation, or geomorphology, water howellia populations can persist, as indicated by the populations that were affected by the Crazy Creek fire.

### 3.3 Road Disturbance

In the Swan River watershed five types of roads occur within the buffers surrounding occupied and unoccupied ponds: County, Historic, National Forest System, Private, and State (**Table 7**). Historic roads have been de-commissioned or rehabilitated by the USFS. The year in which each road was built or re-constructed could not be found. It is assumed that most roads have been in existence since the 1970s.

**Table 7. The number, area, and type of road within occupied and unoccupied pond buffers.**

Road Type	Occupied Pond Buffers (number)	Occupied Pond Buffer Areas <sup>1</sup> (hectare)	Unoccupied Pond Buffers (number)	Occupied Pond Buffer Areas <sup>1</sup> (hectare)
County	10	1.38	1	0.05
Historical	2	0.08	4	0.34
National Forest System	95	10.16	21	2.26
Private	6	0.40	7	0.70
State	7	0.84	3	0.37
<b>Total Pond Buffers with Roads</b>	<b>120 (55%)</b>	<b>12.85 ha</b>	<b>36 (42%<sup>2</sup>)</b>	<b>3.73 ha</b>

<sup>1</sup> The area of road is approximate as some source data lacked information.

<sup>2</sup> Percentage of the original 86 ponds identified as unoccupied for water howellia.

A *two-sample proportions* statistical test was performed on the matrix of all observations, positive observations, and proportion of positive observations for occupied pond buffers with



and without roads (**Table 8**). Of the 220 occupied ponds, 120 pond buffers contain roads while the remaining 100 pond buffers lack roads (**Table 8**). The percentage of positive observations was higher in ponds surrounded by a buffer with at least one road (86%) than for pond buffers that lacked roads (83%); however, this difference was not statistically significant (X-squared = 1.5494, df = 1, p-value = 0.2132; 95% confidence interval ranged from -0.01413 to 0.06547). The 3% difference in positive water howellia observations is also biologically small. This analysis indicates that the presence of at least one road in the buffer has had little influence on the presence or absence of water howellia.

**Table 8. Positive and total observation data for water howellia at ponds with buffers that contain or lack roads.**

Occupied Ponds	Pond Buffers (number)	Positive Water Howellia Observations (number)	Total Observations (number)	Percentage of Positive Observations
Buffer with Road(s)	120	655	766	86%
Buffer without Road(s)	100	530	639	83%

In conclusion, most roads that occur in pond buffers have been present in the landscape for a long time, and likely are older than 1978. Although this study cannot determine a cause and effect relationship, it indicates that the presence of water howellia has not been hindered by road development. However, this could be due in part to better road management which since the 1990's has been more sensitive to the potential impacts that roads may have on pond function and ecology. The Conservation Strategy recommends to not spray herbicides on roadsides adjacent to occupied and unoccupied ponds. This "no spray" zone reduces the potential for toxic chemicals to enter the water and possibly harm the plant. Roads that bisect ponds have been built with properly sized culverts to maintain water levels and flow. It is also probable that the need to build roads through pond buffers has been reduced. Implementing recommendations from the Conservation Strategy and applying best management practices for road maintenance has likely helped water howellia persist with the current network of road systems. However, the persistence of water howellia in the Swan River watershed is largely dependent upon a balance of adequate precipitation and pond drying on an annual basis.

### 3.4 Livestock Grazing Disturbance

Livestock grazing by cattle around occupied water howellia ponds was investigated by the USFS on land managed by the Flathead National Forest. An extensive inventory was conducted in 1995 to determine which ponds were affected by cattle use (Hoang 2007). Livestock grazing was found to be present at four occupied water howellia ponds: EOs 46, 47, 72, and 82. At this time the concern was that livestock grazing could negatively impact water howellia through ground disturbing activities, such as trampling and compacting soil. In 1997 and 1998 barricades were constructed at four water howellia ponds to prevent access by cattle (Hoang 2007). At the EO 46 and EO 47 ponds fences were built while at the EO 72 and EO 82 ponds brush was densely piled to prevent use by cattle (Mantas personal communication). Of these four ponds, EOs 46, 47, and 72 were included in the USFS 1998-2007 monitoring study, which also assessed cattle use. However, after 1999 EO 46 was removed from the study due to marginal habitat conditions for water howellia (Mantas 1999). The fence around EO 47 remained intact through

2007 (Shelly and Marsh 2007). The fence around EO 72 is presumed to have remained intact during the length of the study, but monitoring comments by the observer in 2007 did not mention the fence. Livestock grazing was observed to be absent around EO 46 from 1998-1999 and around EOs 47 and 72 from 1998-2007 (Mantas 1999; Shelly and Marsh 2007). Cattle use was not seen at the remaining 113 to 119 occupied and unoccupied ponds included in the USFS 1998-2007 monitoring study (Hoang 2007).

The persistence of water howellia was examined from 1978 to 2014 at EOs 46, 47, 72, and 82 where the 1995 survey detected cattle use.

- At EO 46 water howellia was found to be present in the years of 1987 and 1989-1991, which predate installation of the 1997/1998 fence (**Table A-4 in Appendix A**). Water howellia was found to be absent in 1997 to 1999 but in 2013 was present (**Table A-4 in Appendix A**). It should be noted that the pond was only partially surveyed in 1999. The amount of cattle use remains unknown, but it can be inferred that cattle use has not hindered the persistence of water howellia. Further the presence of water howellia in 2013 indicates that the plant survives in a pond deemed to be of marginal quality and fenced from cattle activity.
- At EO 47 water howellia was found to be present in the years of 1987 and 1989-1991, which predate installation of the 1997/1998 fence (**Table A-4 in Appendix A**). Water howellia was found to be absent in 1997 and present from 1998-2007 and in 2013 (**Table A-4 in Appendix A**). Therefore, it can be inferred that cattle use did not hinder the presence of water howellia, although the amount of use is unknown. In 2013, water howellia has survived in a pond fenced from cattle activity. Since then the pond has not been visited.
- At EO 72 water howellia was first found in 1995, which is also the year that cattle activity was noted (**Table A-4 in Appendix A**). Brush piles were made in 1997/1998. In each year from 1997-2007, water howellia was present and cattle activity was not found (**Table A-4 in Appendix A**). In 2010, the last year in which the pond was visited, water howellia was seen in high abundance, and the observation record made no mention of cattle activity (MTNHP 2016) (**Table A-4 in Appendix A**). Therefore, it can be inferred that the barricade prevented cattle access from at least 1997-2007.
- At EO 82, water howellia was first found in 1995, which is also the year that cattle activity was noted (**Table A-4 in Appendix A**). Brush piles were made in 1997/1998. Water howellia was found to be present in 1997 (**Table A-4 in Appendix A**). Since then the pond has not been visited.

In conclusion, livestock grazing by cattle can occur in habitat occupied by water howellia and in adjacent forested buffers. From 1978-2014 it appears that livestock use is low throughout the geographical boundaries of the occupied and unoccupied ponds. Where livestock grazing was present, management actions protected the integrity of the pond and buffer by installing barricades. Although no cause and effect relationship can be determined, water howellia has persisted in the 4 ponds where livestock grazing was observed and management actions enacted.

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## Appendix A

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*Table A-1. Characteristics of Water Howellia Occupied Ponds and Buffers in Montana.*

*Table A-2. Characteristics of Unoccupied Ponds and Buffers in Montana.*

*Table A-3. Codes and Abbreviations Used in Table A-4.*

*Table A-4. Timeline Displaying Presence or Absence of Water Howellia Surveys at Ponds and the Stand Treatments and Fire Events that Occurred in 300-foot Pond Buffers from 1978-2015.*

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**Table A-1. Characteristics of each occupied water howellia pond and 300-foot buffer in Montana. Abbreviations: EO = Element Occurrence; P = Present for water howellia; A = absent for water howellia.**

Occupied Pond Number (EO)	Pond Size (acre)	2015 Ownership of Pond	Buffer Size (acre)	2015 Ownership of Buffer	Disturbance Type(s) in Buffer	First Pond Observation Year	First Observation	Last Pond Observation Year	Last Observation	Total Presence Observations, 1978-2014 (count)	Total Absence Observations, 1978-2014 (count)	Total of All Observations, 1978-2014 (count)	Proportion of Positive Observations, 1978-2014
1	0.41	Federal	10.04	Federal	Stand Treatment	1984	P	2012	A	15	2	17	0.882
2	2.97	Federal	21.13	Federal	Stand Treatment	1984	P	2012	P	6	1	7	0.857
3	0.40	Private	10.60	Private		1983	P	1997	P	2	0	2	1.000
4	1.18	Private	13.24	Private	Road	1978	P	1997	A	3	1	4	0.750
5	2.31	TNC	14.96	TNC		1987	P	1987	P	1	0	1	1.000
6	0.62	Federal	11.26	Federal	Stand Treatment	1986	P	2007	P	15	0	15	1.000
7	0.73	Federal	12.53	Federal, State		1987	P	2007	P	16	0	16	1.000
8	0.45	Federal	10.04	Federal		1987	P	2007	P	19	1	20	0.950
9	1.25	Federal	12.72	Federal		1987	P	2007	P	16	4	20	0.800
10	0.41	Federal	10.30	Federal	Road	1987	P	2007	A	7	5	12	0.583
11	4.85	Federal	21.60	Federal	Road	1987	P	2007	P	3	0	3	1.000
12	0.64	Federal	10.60	Federal	Road	1987	P	2011	P	13	2	15	0.867
13	0.91	Federal	11.65	Federal		1987	P	2007	P	18	2	20	0.900
14	0.43	Federal	9.80	Federal	Road	1987	P	2007	P	13	2	15	0.867
15	0.28	Federal	9.19	Federal		1987	P	2007	P	10	2	12	0.833
16	0.60	Federal	10.71	Federal	Road	1987	P	2007	P	14	1	15	0.933
17	1.11	Federal	12.12	Federal	Road	1987	P	2007	P	3	3	6	0.500
18	0.98	Federal	11.25	Federal	Stand Treatment, Road	1987	P	2007	P	11	1	12	0.917
19	1.63	Federal	12.51	Federal	Stand Treatment	1987	P	2007	P	10	2	12	0.833
20	0.42	Federal	8.39	Federal	Stand Treatment	1986	P	2007	P	20	1	21	0.952
21	1.90	Federal	15.46	Federal	Stand Treatment, Road	1986	P	2007	P	3	1	4	0.750
22	0.09	Federal	7.59	Federal	Stand Treatment	1987	P	2007	P	14	1	15	0.933
23	0.38	Federal	10.25	Federal	Stand Treatment, Road	1986	P	2007	A	14	2	16	0.875
24	0.42	Federal	10.17	Federal	Stand Treatment, Road	1987	P	2007	P	11	1	12	0.917
25	0.68	Federal	10.88	Federal	Stand Treatment, Road	1987	P	2007	P	11	4	15	0.733
26	0.46	Federal	10.63	Federal	Stand Treatment, Road	1987	P	2006	P	14	0	14	1.000
27	0.88	Federal	12.73	Federal	Stand Treatment	1987	P	2007	P	18	2	20	0.900
28	0.34	Federal	9.66	Federal	Stand Treatment	1987	P	2012	P	7	4	11	0.636
29	0.54	Federal	11.07	Federal	Stand Treatment	1987	P	2012	P	9	5	14	0.643
30	0.39	Federal	10.50	Federal	Stand Treatment	1987	P	2012	P	10	4	14	0.714
31	0.66	Federal	11.17	Federal	Road	1987	P	2012	P	7	4	11	0.636
32	0.33	Private	10.43	Private		1983	P	2012	P	6	0	6	1.000
33	2.00	Private	16.03	Private	Road	1983	P	2012	P	3	0	3	1.000
34	0.32	Private	9.52	Private		1983	P	2012	P	3	0	3	1.000
35	0.25	Private	9.89	Private		1983	P	2012	P	5	1	6	0.833
36	0.32	Federal	10.05	Federal/Private	Road	1987	P	2012	P	5	0	5	1.000
37	1.34	Federal	15.74	Federal	Stand Treatment	1987	P	2012	P	12	1	13	0.923
38	1.29	Federal	13.64	Federal	Stand Treatment, Road	1987	P	2012	P	5	1	6	0.833
39	0.98	Federal	12.28	Federal	Stand Treatment, Road	1984	P	2012	P	6	1	7	0.857

Occupied Pond Number (EO)	Pond Size (acre)	2015 Ownership of Pond	Buffer Size (acre)	2015 Ownership of Buffer	Disturbance Type(s) in Buffer	First Pond Observation Year	First Observation	Last Pond Observation Year	Last Observation	Total Presence Observations, 1978-2014 (count)	Total Absence Observations, 1978-2014 (count)	Total of All Observations, 1978-2014 (count)	Proportion of Positive Observations, 1978-2014
40	0.43	Federal	11.51	Federal	Stand Treatment	1984	P	2012	P	5	2	7	0.714
41	0.73	Private	10.79	Federal, Private	Stand Treatment	1987	P	1987	P	1	0	1	1.000
42	1.93	Private	15.87	Private		1987	P	1987	P	1	0	1	1.000
43	0.23	Federal	9.29	Federal		1987	P	2007	P	9	3	12	0.750
44	0.48	Federal	12.46	Federal	Road	1987	P	2011	P	16	2	18	0.889
45	1.19	Federal	15.37	Federal	Stand Treatment, Road	1987	P	2007	P	15	1	16	0.938
46	2.20	Federal	15.49	Federal	Stand Treatment, Road, Grazing	1987	P	2013	P	5	1	6	0.833
47	0.68	Federal	11.63	Federal	Stand Treatment, Road, Grazing	1987	P	2013	P	15	1	16	0.938
48	0.37	Federal	10.84	Federal	Road	1987	P	2013	P	15	1	16	0.938
49	0.60	Private	13.23	Federal, Private	Road	1987	P	2013	P	7	0	7	1.000
50	1.47	Private	13.39	Federal, Private		1987	P	1987	P	1	0	1	1.000
51	0.16	Private	9.48	Private	Road	1987	P	1997	P	2	0	2	1.000
52	1.41	Private	14.79	Private	Road	1987	P	1997	P	2	0	2	1.000
53	3.09	Federal, Private	20.98	Federal, Private		1988	P	2007	P	3	0	3	1.000
54	3.48	Federal	18.12	Federal	Stand Treatment, Road	1988	P	2012	P	11	1	12	0.917
55	1.77	Federal	15.63	Federal	Stand Treatment, Road	1988	P	2007	P	12	0	12	1.000
56	0.55	Federal	13.58	Federal		1989	P	2007	P	9	3	12	0.750
57	1.22	Federal	15.49	Federal		1989	P	2007	P	5	7	12	0.417
58	0.29	Private	9.37	Federal, Private	Road	1990	P	2007	P	2	0	2	1.000
59	0.31	Federal	9.80	Federal	Stand Treatment	1995	P	2012	A	4	3	7	0.571
60	0.93	Federal	12.33	Federal	Stand Treatment	1995	P	2012	P	6	1	7	0.857
61	0.17	Federal	8.81	Federal	Stand Treatment	1995	P	2007	P	9	3	12	0.750
62	0.68	Federal	11.74	Federal		1995	P	2007	P	9	3	12	0.750
63	0.35	Federal, Private	9.77	Federal, Private	Stand Treatment	1995	P	2007	P	2	1	3	0.667
64	0.85	Private	12.56	Federal, Private		1995	P	1997	P	2	0	2	1.000
65	2.35	Federal	19.64	Federal	Stand Treatment, Road	1995	P	2012	P	4	2	6	0.667
66	1.45	Federal	13.64	Federal	Stand Treatment	1995	P	2012	P	5	1	6	0.833
67	1.73	Federal	14.20	Federal	Stand Treatment, Road	1995	P	2012	P	5	1	6	0.833
68	0.72	Federal	11.96	Federal, Private	Stand Treatment, Road	1995	P	2012	P	5	1	6	0.833
69	0.89	Federal	12.82	Federal	Stand Treatment, Road	1995	P	2012	P	4	2	6	0.667
70	0.34	Federal	9.57	Federal	Stand Treatment	1995	P	2007	A	10	2	12	0.833
71	0.18	Federal	8.96	Federal	Stand Treatment, Road	1995	P	2007	P	12	0	12	1.000
72	0.50	Federal	11.28	Federal	Stand Treatment, Road, Grazing	1995	P	2010	P	13	0	13	1.000
73	0.46	Federal	10.05	Federal	Stand Treatment, Road	1995	P	2008	P	11	1	12	0.917
74	0.43	Federal	9.70	Federal		1995	P	2007	P	12	0	12	1.000
75	0.14	Federal	8.29	Federal	Road	1995	P	2007	P	11	1	12	0.917
76	2.11	Federal	14.93	Federal	Stand Treatment, Road	1995	P	2006	P	11	0	11	1.000
77	0.34	Private	9.88	Federal, Private	Road	1995	P	1997	P	2	0	2	1.000
78	0.38	Federal	10.54	Federal		1995	P	2007	P	11	1	12	0.917
79	0.53	Federal	9.94	Federal	Stand Treatment	1995	P	2007	P	11	1	12	0.917



Occupied Pond Number (EO)	Pond Size (acre)	2015 Ownership of Pond	Buffer Size (acre)	2015 Ownership of Buffer	Disturbance Type(s) in Buffer	First Pond Observation Year	First Observation	Last Pond Observation Year	Last Observation	Total Presence Observations, 1978-2014 (count)	Total Absence Observations, 1978-2014 (count)	Total of All Observations, 1978-2014 (count)	Proportion of Positive Observations, 1978-2014
80	0.90	Federal	11.28	Federal	Stand Treatment	1995	P	2007	P	10	2	12	0.833
81	0.85	Federal	13.75	Federal	Stand Treatment, Road	1995	P	2007	P	12	0	12	1.000
82	3.79	Federal	23.96	Federal	Stand Treatment, Road, Grazing	1995	P	1997	P	2	0	2	1.000
83	0.45	Federal	10.78	Federal	Stand Treatment, Road	1995	P	2012	P	6	2	8	0.750
84	0.25	Federal	9.15	Federal	Road	1995	P	2007	A	9	3	12	0.750
85	1.67	Private	16.58	Private	Road	1995	P	1997	P	2	0	2	1.000
86	0.32	Federal	10.35	Federal, Private	Stand Treatment	1995	P	2007	P	12	0	12	1.000
87	0.44	Federal	11.62	Federal	Stand Treatment	1995	P	2007	P	12	0	12	1.000
88	0.78	Federal	13.05	Federal	Road	1995	P	2007	P	2	1	3	0.667
89	0.57	Federal, Private	11.52	Federal, Private		1995	P	2012	P	4	0	4	1.000
90	0.16	Federal	8.85	Federal	Road	1995	P	2007	P	11	1	12	0.917
91	0.26	Federal	9.47	Federal	Stand Treatment, Road	1995	P	2007	P	11	1	12	0.917
92	0.57	Federal	11.28	Federal	Road	1995	P	2012	P	8	2	10	0.800
93	0.15	Federal	8.60	Federal	Road	1995	P	2012	P	10	0	10	1.000
94	0.58	Federal	11.63	Federal	Stand Treatment	1995	P	2007	P	10	2	12	0.833
95	0.37	Federal	10.06	Federal	Road	1995	P	2007	P	9	3	12	0.750
96	0.52	Federal	10.97	Federal		1995	P	2007	P	8	4	12	0.667
97	0.26	Federal	9.23	Federal		1995	P	2007	P	9	3	12	0.750
98	0.32	Federal	10.82	Federal	Road	1995	P	2007	P	12	0	12	1.000
99	0.32	Federal	10.08	Federal	Road	1995	P	2007	P	11	1	12	0.917
100	0.24	Federal	9.23	Federal	Road	1995	P	2010	P	12	1	13	0.923
101	0.34	Federal	9.64	Federal	Stand Treatment, Road	1995	P	2007	P	11	1	12	0.917
102	0.81	Federal	12.69	Federal	Stand Treatment	1997	P	2007	P	11	0	11	1.000
103	0.25	Federal	9.71	Federal	Stand Treatment	1997	P	2007	P	5	6	11	0.455
104	0.61	Federal	12.54	Federal	Road	1997	P	2007	P	11	0	11	1.000
105	2.31	Federal	18.25	Federal	Stand Treatment	1997	P	2007	P	2	0	2	1.000
106	0.44	Federal	10.58	Federal	Stand Treatment, Road	1998	P	2007	P	8	2	10	0.800
107	0.30	Federal	9.44	Federal	Stand Treatment, Road	1998	P	2013	P	11	1	12	0.917
108	2.03	Federal	21.29	Federal	Road	1999	P	2007	P	9	1	10	0.900
109	0.88	Federal	14.31	Federal, Private	Stand Treatment, Road	1998	A	2007	P	9	1	10	0.900
110	0.52	Federal	12.14	Federal	Stand Treatment, Road	2000	P	2012	P	5	3	8	0.625
111	0.25	Federal	9.41	Federal	Road	1998	A	2007	P	8	2	10	0.800
112	1.35	Federal	13.67	Federal	Stand Treatment, Road	1998	A	2007	P	8	2	10	0.800
113	0.17	Federal	8.54	Federal		1995	A	2007	P	8	2	10	0.800
114	0.73	Federal	12.41	Federal	Stand Treatment, Road	1999	P	2012	P	6	1	7	0.857
115	1.12	State	14.24	State	Road	2000	P	2012	P	4	1	5	0.800
116	0.34	Federal	11.06	Federal, State		2000	P	2007	P	2	0	2	1.000
117	0.64	State	12.38	State	Road	2000	P	2007	P	2	0	2	1.000
118	0.49	Federal	11.22	Federal	Stand Treatment	2000	P	2000	P	1	0	1	1.000
119	0.73	Private	11.14	Private	Road	2000	P	2007	P	2	0	2	1.000

Occupied Pond Number (EO)	Pond Size (acre)	2015 Ownership of Pond	Buffer Size (acre)	2015 Ownership of Buffer	Disturbance Type(s) in Buffer	First Pond Observation Year	First Observation	Last Pond Observation Year	Last Observation	Total Presence Observations, 1978-2014 (count)	Total Absence Observations, 1978-2014 (count)	Total of All Observations, 1978-2014 (count)	Proportion of Positive Observations, 1978-2014
120	0.26	Private	9.10	Private	Road	2000	P	2007	A	1	1	2	0.500
121	1.16	Private	14.09	Private		2000	P	2007	P	2	0	2	1.000
122	1.06	Private	12.36	Private		2000	P	2007	P	2	0	2	1.000
123	0.42	Federal	10.55	Federal	Stand Treatment, Road	2000	P	2012	P	3	1	4	0.750
124	0.18	Federal	8.44	Federal	Stand Treatment, Road	2000	P	2011	A	3	1	4	0.750
125	1.08	Federal	13.39	Federal	Stand Treatment, Road	2000	P	2011	A	3	1	4	0.750
126	0.21	Federal	8.94	Federal	Stand Treatment	2000	P	2012	P	3	1	4	0.750
127	0.57	Federal	11.52	Federal	Road	2000	P	2012	P	3	0	3	1.000
128	1.50	Federal	15.69	Federal, Private	Stand Treatment, Road	2000	P	2010	P	2	0	2	1.000
129	0.80	Federal	11.98	Federal	Road	2000	P	2012	P	3	0	3	1.000
130	0.55	Federal	10.85	Federal	Road	1990	P	2012	A	4	4	8	0.500
131	0.34	Federal	11.18	Federal	Stand Treatment	1999	A	2013	P	2	2	4	0.500
132	2.15	Federal	18.12	Federal, TNC		1985	P	1997	A	2	1	3	0.667
133	12.74	Federal, TNC	32.09	Federal, TNC		1985	P	1997	A	2	1	3	0.667
134	0.31	TNC	9.46	TNC		1987	P	1997	A	1	1	2	0.500
135	0.39	Federal	10.09	Federal	Stand Treatment, Road	2004	P	2012	P	5	2	7	0.714
136	0.15	Federal	8.58	Federal	Stand Treatment, Fire	2004	P	2004	P	1	0	1	1.000
137	0.10	Federal	8.15	Federal	Stand Treatment, Fire, Road	2004	P	2004	P	1	0	1	1.000
138	0.20	Federal	9.02	Federal	Stand Treatment, Fire	2004	P	2010	A	1	1	2	0.500
139	0.39	Federal	10.36	Federal	Stand Treatment, Fire	2004	P	2012	P	3	0	3	1.000
140	1.04	Federal	11.01	Federal	Stand Treatment	1998	A	2012	P	3	4	7	0.429
141	0.41	State	10.35	State	Road	2003	P	2012	P	2	0	2	1.000
142	0.05	Federal	7.46	Federal	Road	2007	P	2007	P	1	0	1	1.000
143	0.35	Federal	9.94	Federal	Stand Treatment, Road	2007	P	2012	A	1	1	2	0.500
144	0.46	Federal	10.11	Federal, Private	Stand Treatment, Road	2007	P	2012	P	2	2	4	0.500
145	1.26	Federal	14.30	Federal	Stand Treatment, Road	2007	P	2012	A	2	2	4	0.500
146	2.38	Federal	17.32	Federal	Stand Treatment	2007	P	2012	P	3	1	4	0.750
147	0.84	Federal	12.53	Federal	Stand Treatment, Road	2007	P	2012	A	1	3	4	0.250
148	0.15	Federal	8.97	Federal	Stand Treatment, Road	2007	P	2008	P	2	0	2	1.000
149	3.51	Federal, TNC	20.56	Federal, TNC		1987	P	1997	A	1	1	2	0.500
150	1.66	TNC	16.36	Federal, TNC		1987	P	1997	A	1	1	2	0.500
151	0.31	Federal	9.32	Federal	Stand Treatment	2005	P	2010	A	1	1	2	0.500
152	0.37	Federal	10.55	Federal	Stand Treatment, Road	1998	A	2012	P	3	4	7	0.429
153	0.26	Federal	9.83	Federal	Stand Treatment	2005	P	2013	P	3	0	3	1.000
154	0.14	Federal	8.47	Federal	Stand Treatment, Road	2006	P	2012	A	2	1	3	0.667
155	1.71	Federal	14.81	Federal		2008	P	2008	P	1	0	1	1.000
156	1.91	Federal	17.25	Federal	Stand Treatment, Road	2008	P	2008	P	1	0	1	1.000
157	0.87	Federal	11.69	Federal	Stand Treatment	2008	P	2008	P	1	0	1	1.000
158	1.81	Federal	14.47	Federal	Stand Treatment, Road	2008	P	2012	P	4	0	4	1.000
159	0.22	Federal	8.61	Federal		2008	P	2012	P	4	0	4	1.000

Occupied Pond Number (EO)	Pond Size (acre)	2015 Ownership of Pond	Buffer Size (acre)	2015 Ownership of Buffer	Disturbance Type(s) in Buffer	First Pond Observation Year	First Observation	Last Pond Observation Year	Last Observation	Total Presence Observations, 1978-2014 (count)	Total Absence Observations, 1978-2014 (count)	Total of All Observations, 1978-2014 (count)	Proportion of Positive Observations, 1978-2014
160	0.38	Federal	9.82	Federal		2008	P	2012	P	3	1	4	0.750
161	1.16	Federal	13.28	Federal	Stand Treatment, Road	2008	P	2012	A	1	1	2	0.500
162	2.91	Federal	18.91	Federal	Stand Treatment	2008	P	2008	P	1	0	1	1.000
163	1.11	Federal	13.81	Federal		2008	P	2013	P	3	0	3	1.000
164	1.23	Federal	13.41	Federal, Private	Stand Treatment, Road	2008	P	2012	A	2	2	4	0.500
165	0.17	Federal	8.36	Federal, Private	Stand Treatment, Road	2008	P	2008	P	1	0	1	1.000
166	0.46	Federal	10.13	Federal, Private	Stand Treatment	2008	P	2012	A	2	2	4	0.500
167	0.92	Federal, Private	12.40	Federal, Private	Stand Treatment	2008	P	2012	P	3	1	4	0.750
168	0.07	Federal	8.02	Federal	Stand Treatment, Road	2008	P	2008	P	1	0	1	1.000
169	0.13	Federal	8.72	Federal	Stand Treatment, Road	2008	P	2012	P	3	1	4	0.750
170	0.14	Federal	8.86	Federal, Private	Stand Treatment, Road	2008	P	2012	P	3	1	4	0.750
171	0.56	Federal	11.57	Federal	Stand Treatment, Road	2008	P	2012	P	3	1	4	0.750
172	0.44	Federal	10.35	Federal	Stand Treatment	2008	P	2008	P	1	0	1	1.000
173	0.25	Federal	9.40	Federal	Stand Treatment, Fire	2008	P	2015	P	3	1	4	0.750
174	0.37	Federal	9.67	Federal	Stand Treatment, Fire	2008	P	2015	P	4	0	4	1.000
175	0.39	Federal	9.11	Federal	Stand Treatment, Fire	2008	P	2015	P	3	1	4	0.750
176	0.64	Federal	11.56	Federal	Stand Treatment, Fire	2008	P	2015	P	3	1	4	0.750
177	0.12	Federal	8.43	Federal, Private	Stand Treatment, Road	2008	P	2012	P	3	0	3	1.000
178	0.05	Federal	7.77	Federal, Private	Stand Treatment, Road	2008	P	2012	P	4	0	4	1.000
179	0.31	Federal	9.32	Federal	Stand Treatment	2008	P	2012	P	2	0	2	1.000
180	0.17	Federal	8.76	Federal	Stand Treatment, Road	2008	P	2012	P	2	0	2	1.000
181	0.08	Private	7.90	Private	Road	2008	P	2008	P	1	0	1	1.000
182	0.12	Federal	8.57	Federal	Stand Treatment	2009	P	2012	P	3	1	4	0.750
183	0.87	Federal	13.82	Federal	Stand Treatment, Road	2009	P	2012	A	3	1	4	0.750
184	0.64	Federal	14.03	Federal	Stand Treatment, Road	2009	P	2012	P	3	1	4	0.750
185	1.51	Federal, Private	13.07	Federal, Private	Stand Treatment	2009	P	2012	A	2	2	4	0.500
186	0.53	Federal	10.91	Federal	Stand Treatment, Road	2009	P	2012	P	3	1	4	0.750
187	0.49	Federal	13.04	Federal	Stand Treatment, Road	2009	P	2012	P	3	1	4	0.750
188	0.27	Federal	9.71	Federal, Private	Stand Treatment, Road	2009	P	2012	P	4	0	4	1.000
189	1.53	Federal	15.85	Federal	Stand Treatment, Road	2009	P	2012	P	3	1	4	0.750
190	0.18	Federal	8.81	Federal	Stand Treatment, Road	2009	P	2012	P	4	0	4	1.000
191	0.32	Federal	9.58	Federal, Private	Road	2009	P	2010	P	2	0	2	1.000
192	0.08	Federal	7.90	Federal	Road	2009	P	2009	P	1	0	1	1.000
193	0.51	Federal	12.08	Federal	Stand Treatment, Road	2009	P	2009	P	1	0	1	1.000
194	0.39	Federal, Private	10.03	Federal, Private	Stand Treatment, Road	2009	P	2009	P	1	0	1	1.000
195	0.08	Federal	7.34	Federal	Stand Treatment, Road	2009	P	2009	P	1	0	1	1.000
196	0.57	Federal	11.77	Federal	Stand Treatment, Road	2009	P	2009	P	1	0	1	1.000
197	0.73	Federal	12.24	Federal	Stand Treatment	2009	P	2012	P	3	1	4	0.750
198	1.04	Federal	14.20	Federal	Stand Treatment	2009	P	2009	P	1	0	1	1.000
199	0.57	Federal	10.96	Federal	Stand Treatment, Road	2009	P	2012	P	3	1	4	0.750
200	0.43	Federal	9.58	Federal	Stand Treatment, Road	2009	P	2012	P	3	1	4	0.750

Occupied Pond Number (EO)	Pond Size (acre)	2015 Ownership of Pond	Buffer Size (acre)	2015 Ownership of Buffer	Disturbance Type(s) in Buffer	First Pond Observation Year	First Observation	Last Pond Observation Year	Last Observation	Total Presence Observations, 1978-2014 (count)	Total Absence Observations, 1978-2014 (count)	Total of All Observations, 1978-2014 (count)	Proportion of Positive Observations, 1978-2014
201	1.14	Federal	12.88	Federal	Stand Treatment, Road	2009	P	2012	P	3	1	4	0.750
202	0.21	Federal	9.01	Federal		2010	P	2010	P	1	0	1	1.000
203	0.90	Federal	11.73	Federal		2010	P	2010	P	1	0	1	1.000
204	1.22	Federal	13.29	Federal	Road	2010	P	2010	P	1	0	1	1.000
205	1.70	Federal	14.56	Federal		2010	P	2010	P	1	0	1	1.000
206	1.14	Federal	13.02	Federal		2010	P	2010	P	1	0	1	1.000
207	0.46	Federal	11.21	Federal		2010	P	2010	P	1	0	1	1.000
208	0.37	Federal	10.66	Federal	Stand Treatment	2010	P	2010	P	1	0	1	1.000
209	1.10	Federal	13.26	Federal	Stand Treatment, Road	2010	P	2010	P	1	0	1	1.000
210	0.26	Federal	9.24	Federal		2010	P	2010	P	1	0	1	1.000
211	1.13	Federal	13.74	Federal		2010	P	2010	P	1	0	1	1.000
212	0.23	Federal	9.02	Private, Federal		2010	P	2012	P	2	0	2	1.000
213	0.07	Federal	8.13	Federal		2011	P	2012	P	2	0	2	1.000
214	0.14	Federal	8.35	Federal		2011	P	2011	P	1	0	1	1.000
215	0.18	Federal	8.88	Federal		2011	P	2011	P	1	0	1	1.000
216	0.31	State	10.24	Federal, State	Road	2011	P	2011	P	1	0	1	1.000
217	4.35	Federal	20.11	Federal	Stand Treatment, Road	1988	P	1988	P	1	0	1	1.000
218	3.32	Federal	17.54	Federal	Stand Treatment, Road	2011	P	2011	P	1	0	1	1.000
219	6.14	Federal	26.30	Federal	Stand Treatment, Road	2013	P	2013	P	1	0	1	1.000
220	0.04	Private	7.65	Private	Road	2014	P	2014	P	1	0	1	1.000

**Table A-2. Characteristics of each unoccupied pond and 300-foot buffer in Montana. Abbreviations: EO = Element Occurrence; A = absent for water howellia.**

<b>Unoccupied (U-) Pond Number</b>	<b>U-Pond Size (acre)</b>	<b>U-Pond Buffer Size (acre)</b>	<b>2015 Ownership of Buffer</b>	<b>Disturbance Type(s) in Buffer</b>	<b>First Pond Observation Year</b>	<b>First Observation</b>	<b>Last Pond Observation Year</b>	<b>Last Observation</b>
u-001	0.13	8.63	Federal, Private		1987	A	2007	A
u-002	0.01	7.00	Federal	Stand Treatment, Road	1999	A	2006	A
u-003	0.25	9.99	Federal	Road	1998	A	2007	A
u-004	0.01	7.10	Federal	Stand Treatment, Road	1999	A	2006	A
u-005	0.03	7.33	Federal	Stand Treatment, Road	1999	A	2006	A
u-006	1.03	11.81	Federal		1987	A	2006	A
u-007	0.41	10.42	Federal	Stand Treatment	1987	A	2006	A
u-008	0.66	11.00	State		1987	A	2007	A
u-009	1.86	15.79	Federal	Road	1987	A	1989	A
u-011	0.73	11.00	State		1988	A	2006	A
u-012	1.50	13.23	State		1988	A	2006	A
u-013	0.27	9.45	Federal, State		1988	A	2006	A
u-014	0.54	10.85	Federal		1988	A	2007	A
u-015	0.60	11.10	Federal	Stand Treatment, Road	1988	A	2007	A
u-016	0.59	11.00	Federal	Road	1998	A	2006	A
u-018	1.72	15.14	Federal, Private	Stand Treatment	unknown	A	unknown	A
u-019	1.59	14.77	Federal, State	Stand Treatment, Road	1987	A	2006	A
u-020	0.56	11.19	Federal, State	Stand Treatment, Road	1987	A	2006	A
u-021	0.35	9.93	Federal, Private	Stand Treatment, Road	1988	A	2006	A
u-022	2.76	18.57	Federal	Road	1988	A	2007	A
u-023	0.05	7.72	Federal	Stand Treatment	unknown	A	unknown	A
u-025	0.27	9.21	Federal		1999	A	2007	A
u-026	0.03	7.47	Federal	Stand Treatment	unknown	A	unknown	A
u-027	0.69	12.97	Federal		1988	A	2007	A
u-028	2.28	18.72	Private		1987	A	1989	A
u-029	2.33	17.93	Federal		1987	A	1989	A

Unoccupied (U-) Pond Number	U-Pond Size (acre)	U-Pond Buffer Size (acre)	2015 Ownership of Buffer	Disturbance Type(s) in Buffer	First Pond Observation Year	First Observation	Last Pond Observation Year	Last Observation
u-030	0.27	9.48	Federal	Stand Treatment	1998	A	2004	A
u-033	0.83	11.37	Federal	Stand Treatment	1987	A	1989	A
u-034	0.86	11.82	Federal	Stand Treatment	unknown	A	unknown	A
u-035	4.15	27.19	Unknown	Stand Treatment, Road	unknown	A	unknown	A
u-036	1.01	12.19	Unknown		unknown	A	unknown	A
u-037	3.83	18.18	Federal		unknown	A	unknown	A
u-038	1.82	15.00	Federal		1987	A	1988	A
u-039	1.45	14.78	Federal	Stand Treatment, Road	1987	A	1988	A
u-040	0.18	8.34	Federal, Private		1987	A	1988	A
u-041	0.19	8.38	Federal, Private	Stand Treatment	1987	A	2007	A
u-042	0.24	9.02	Federal, Private	Stand Treatment	1987	A	2007	A
u-043	0.28	9.34	Federal, Private	Stand Treatment	1987	A	2007	A
u-044	0.26	9.35	Federal	Stand Treatment	unknown	A	unknown	A
u-045	0.26	8.73	Federal, Private	Stand Treatment	1987	A	2007	A
u-046	0.08	8.04	Federal		1999	A	2010	A
u-047	0.57	10.83	Unknown	Stand Treatment	1998	A	2006	A
u-048	0.38	10.13	Federal, Private		1989	A	2007	A
u-049	0.64	10.99	State	Stand Treatment, Road	1988	A	2006	A
u-050	7.95	28.55	State	Road	1987	A	1988	A
u-051	0.02	7.12	Federal	Road	2010	A	2010	A
u-054	0.64	11.16	Federal, Private	Stand Treatment	unknown	A	unknown	A
u-055	0.39	10.86	Federal	Stand Treatment, Road	1998	A	2006	A
u-056	0.10	8.10	Federal		1998	A	2007	A
u-057	0.20	8.91	Federal, Private	Road	1998	A	2007	A
u-058	1.66	17.30	Federal	Road	unknown	A	unknown	A
u-059	0.61	10.80	Federal	Road	1998	A	1999	A
u-060	1.64	14.09	Federal, Private	Road	unknown	A	unknown	A
u-061	0.07	7.94	Federal, Private	Stand Treatment	unknown	A	unknown	A

Unoccupied (U-) Pond Number	U-Pond Size (acre)	U-Pond Buffer Size (acre)	2015 Ownership of Buffer	Disturbance Type(s) in Buffer	First Pond Observation Year	First Observation	Last Pond Observation Year	Last Observation
u-062	0.33	9.47	Federal	Stand Treatment	1998	A	2006	A
u-063	0.76	11.73	Federal, Private	Road	unknown	A	unknown	A
u-064	0.10	8.51	Federal	Stand Treatment, Road	1999	A	2007	A
u-065	0.39	9.92	Federal, Private		1998	A	2006	A
u-068	0.38	10.07	Unknown	Stand Treatment	1998	A	2006	A
u-069	1.72	14.90	Federal, Private	Stand Treatment	1987	A	1988	A
u-070	0.17	8.50	Federal, Private	Road	1998	A	2006	A
u-071	0.92	13.13	Federal, Private	Road	1998	A	2006	A
u-072	0.39	10.56	Federal	Stand Treatment, Road	1998	A	2007	A
u-074	0.17	9.27	Unknown	Road	1998	A	2007	A
u-075	0.83	11.56	Private, Unknown	Stand Treatment	1998	A	2007	A
u-077	1.27	12.81	Federal		1987	A	2007	A
u-078	0.31	9.80	Federal, Private, TNC	Stand Treatment, Road	1987	A	1987	A
u-079	0.20	10.43	Private	Road	unknown	A	unknown	A
u-080	0.39	10.08	Private		1987	A	1989	A
u-081	0.37	9.84	Private		1987	A	1989	A
u-082	0.11	8.37	Private	Road	1987	A	1987	A
u-083	0.15	8.93	Private	Road	unknown	A	unknown	A
u-085	0.04	7.68	Federal		1999	A	2007	A
u-086	0.07	7.64	Federal	Stand Treatment, Road	1998	A	2002	A
u-087	0.08	7.83	Federal	Stand Treatment, Road	1998	A	2002	A
u-088	0.14	8.62	Federal	Stand Treatment, Road	1998	A	2006	A
u-089	0.20	8.80	Federal	Stand Treatment	1998	A	2006	A
u-090	0.05	7.24	Federal	Stand Treatment	1998	A	2002	A
u-091	0.21	8.89	Federal, State	Stand Treatment, Road	1998	A	2006	A
u-092	0.06	8.21	Federal		1999	A	2010	A
u-094	0.67	11.04	Federal	Stand Treatment	unknown	A	unknown	A
u-095	0.11	8.18	Federal		1988	A	2007	A



<b>Unoccupied (U-) Pond Number</b>	<b>U-Pond Size (acre)</b>	<b>U-Pond Buffer Size (acre)</b>	<b>2015 Ownership of Buffer</b>	<b>Disturbance Type(s) in Buffer</b>	<b>First Pond Observation Year</b>	<b>First Observation</b>	<b>Last Pond Observation Year</b>	<b>Last Observation</b>
<b>u-096</b>	0.66	11.39	Federal		1988	A	2007	A
<b>u-097</b>	0.46	10.03	Federal	Road	1999	A	2007	A
<b>u-098</b>	0.21	9.22	Federal		1990	A	2007	A
<b>u-099</b>	0.30	9.75	Federal		1999	A	1999	A

**Table A-3. Codes and abbreviations used in Table A-4.**

<b>STAND TREATMENT TYPES &amp; FIRE EVENTS</b>
Group Selection Cut
Improvement Cut
Liberation Cut
Salvage Cut (intermediate treatment, not regeneration)
Seed-tree Final Cut
Seed-tree Preparatory Cut
Seed-tree Seed Cut (with and without leave trees)
Two-aged Seed-tree Seed and Removal Cut (w/res)
Patch Clearcut
Stand Clearcut
Stand Clearcut (w/ leave trees)
Overstory Removal Cut (from advanced regeneration)
Shelterwood Removal Cut
Shelterwood Establishment Cut (with or without leave trees)
Sanitation Cut
Commercial Thin
Fire (not a stand treatment)
P = Water howellia was present in pond in that year.
A = Water howellia was absent in pond in that year.















