The Effects of Structural Clutter and Open Water on Insectivorous Bat Activity in Palustrine Habitats

BIOS 35502: Practicum in Environmental Field Biology

Jessica Lee

Advisor: *Karen Francl*

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Abstract:

I examined relative species activity of six species of bats found in the Upper Peninsula of Michigan across spectra of horizontal and vertical clutter and open water at 32 palustrine sites. Using Anabat II detection systems, I recorded echolocation activity (number of calls per species) at each site. I found that little brown bat activity decreased with increasing vertical clutter ($R^2 = 0.147$, $p = 0.017$), while red bat activity decreased with increasing horizontal clutter ($R^2 = 0.302$, $p = 0.001$). Furthermore, hoary bat activity increased with area of open water ($R^2 = 0.174$, $p = 0.007$), while northern myotis presence showed the opposite trend ($R^2 = 0.224$, $p = 0.004$). I concluded that physical habitat factors seem to influence individual species independently. Second, with the exception of the northern myotis, bat species in this region generally exhibited greater activity in palustrine habitats with lower structural clutter and greater areas of open water.

Introduction:

Insectivorous bat activity as a topic of research in palustrine habitats has been highly undefined in the Upper Peninsula of Michigan (Francl 2005). In particular, the effect of structural clutter within similar sites has been the basis for a wide variety of hypotheses on bat activity. These hypotheses are contingent upon a multiplicity in insectivorous bat response both within and between species. Researchers have speculated that factors influencing these differences in response include size, morphology/wingspan (Aldridge and Rautenbach 1987, Brigham et al. 1997, Jensen et al. 2001), and individual phenotypic plasticity in echolocation calls (Wund 2006) within the given environment.

In the Upper Peninsula of Michigan, there are six potential bat species—the little brown bat (*Myotis lucifugus*), the northern myotis (*Myotis septentrionalis*), the big brown bat (*Eptesicus fuscus*), the hoary bat (*Lasiurus cinereus*), the red bat (*Lasiurus borealis*), and the silver-haired bat (*Lasionycteris noctivagans*). The most common at the University of Notre Dame Environmental Research Center include the little brown bat, the northern myotis, and the big brown bat (Francl 2005). Smaller-bodied species such as the little brown bat seem to show better adaptation to structural clutter (Wund 2006), whereas larger-bodied species avoid highly cluttered spaces and are more commonly identified in open space environments (Aldridge and Rautenbach 1987).

In particular, the little brown bat exhibits activity in environments with dense vegetation (within the forest) as the species has greater maneuverability in tight spaces (Fenton and Barclay 1980). However, in addition to extremely cluttered habitats, little brown bats exhibits phenotypic plasticity across a broad spectrum of vegetation and open water (Wund 2006). By contrast, the northern myotis is not as ubiquitously identified across a spectrum of clutter and exhibits greater activity in habitats with greater degrees of vertical clutter (Brooks and

Ford 2006, Owen et al. 2003). The species has been observed to capture prey directly on vegetation (Caceres and Barclay 2000).

By contrast, larger species such as the big brown bat and both *Lasiurus* species do not have the same capabilities in foraging due to larger wingspans (Owen et al. 2003), and thus different species seem to exhibit a variety of habitat preferences (Siemers and Schnitezler 2004). Though experiments based on response to various forms of structural clutter, both artificially constructed (Brigham et al. 1997) and natural (Wund 2006) have been conducted, activity within and between bat species in relation to open water palustrine habitats specifically remains largely unstudied.

The significance of palustrine habitats is essentially twofold. First, the presence of water provides open spaces in which bats can maneuver with greater facility. Secondly, palustrine habitats provide both invertebrates and water for consumption. Thus bat foraging has been observed over vernal ponds and smaller palustrine habitats. However, no significant relationship between invertebrate abundance and bat activity has been found, suggesting that invertebrate presence alone is adequate to accommodate activity (Francl 2005). Larger palustrine environments witness a greater amount of general bat activity. Brooks and Ford (2006) indicated that bat flight activity over all palustrine habitats is high, but the greatest amount of activity has been observed over lacustrine environments, or permanent ponds. Clutter effects given these conditions of palustrine environments remain somewhat underdeveloped. Thus, observation of bat activity across a broad spectrum of clutter in such habitats can then be used to better define some sort of standard behavior among different species in this region.

In my experiment, I studied the overall bat activity along a spectrum of clutter in different palustrine habitats in Upper Peninsula Michigan. I compared and evaluated differences in echolocation and call recordings among different species to determine relationships between activity, area of open water, and clutter. Based on previous studies between species, I hypothesized that all six species would exhibit some degree of activity in habitats with less structural clutter and more open water. However, little brown bats, and northern myotis alone would exhibit higher activity in areas with high clutter, whereas larger-bodied species such as the hoary, silver-haired, red and big brown bat, would only exhibit high activity in environments which are conducive to maneuverability. I measured bat species presence and relative activity across sites using Anabat II call measures and mist netting efforts in structurally diverse palustrine sites.

Methods:

Site Selection:

The University of Notre Dame Environmental Research Center (UNDERC) is a 3,035 ha area (7500 acres) on the border of northern Wisconsin and the Upper Peninsula of Michigan. Palustrine and other open water sites account for 16 percent of the total area on property. I chose 32 palustrine sites with varying amounts clutter and open water for analysis (Appendix 1, Figure 1).

Habitat Measures:

In order to measure relative clutter at each site, I measured vertical clutter using a range pole, and horizontal clutter using a concave spherical densitometer (Forestry Suppliers, Jackson, MS). I selected 20 random points at each site using a random number table. At each point, I calculated the average of four canopy measures, (one in each cardinal direction) with the densiometer. I then took the average of canopy at each point and then calculated total average and standard deviation by averaging canopy across all 20 points to obtain total percent canopy per site (Appendix 1).

At each point, I also recorded the amount of vertical vegetation for every 0.5-m increment from the ground to 6.5 m of a range pole. I then took the total number of hits (h = vegetation falling within a 10-cm radius of the range pole at each point) and the total number of 0.5-m increments in which hits were recorded (v) and calculated total vegetation volume (Mills et al. 1991):

$$TVV=h/10v$$

I also measured the Levin's diversity index to classify habitat type:

$$L = (\Sigma d_i^2)^{-1}$$

where "d_i" is equal to the proportion of hits in each 0.5-m increment as compared with hits in other increments on the pole (Levins 1968):

For each of the 32 sites, I determined location using a GPS unit and made a map using Arcview 3.3 software (ESRI, Redlands, CA; Figure 1). I then quantified total open water area at each site (Appendix 1). For areas of high canopy cover (>10% cover), I used a measuring tape to measure length and width across the open water. I then employed the equation for elliptical area of water,

$$A = \pi ab$$

where "a" equals half of the length, and "b" equals half of the width:

For areas with canopy less than 10%, I employed the polygon area tool ground-truthing GIS map using a preconstructed DOQQ map of UNDERC (Francl, personal communication) in Arcview 3.3 to determine total open water area.

Bat Surveys:

Bat surveys were conducted through a combination of Anabat II detector equipment and mist-netting. Anabat II detectors were placed on lawn chairs and angled between 30 - 60º over a point overlooking the greatest stretch of open water at each site. Bat calls were recorded from sunset to 0100h (>4h) between June 13 and July 15, 2007. I collected data only on nights with permissible weather conditions (temperature >10ºC [50ºF] and no precipitation). I used a Kestrel 3000 (Niche Retail LLC, Silvan Lake, MI) to record temperature and weather conditions on each night of data collection. I then analyzed calls per site and recorded species using the MS-DOS application, Analook and a known call library index (Francl, unpublished data).

In order to establish support for correct echolocation identification, I collected samples using mist-nets on 10 evenings. In areas of high clutter (>60%), I used a triple-high mist net in conjunction with 2-3 standard mistnets in a “zig-zag” pattern across the open water. In areas with less clutter (0-60%), only standard mistnets, and in some cases, boats were used to collect bat samples across the open water. I recorded time of capture, species, weight, relative age, sex, reproductive condition, forearm length and time of release for each bat captured. I also recorded captures of other non-bat species. Two bats were marked with red sharpie in the event of recapture, and 8 out of the total 15 were shaved.

After all data was collected, I transformed calls by species for each site using the transformation listed below for all species (except little brown bats) based on histogram analysis of data:

$$(\text{Log}_{10}[x + 1])$$

For little brown bats, I transformed total calls per site using $\text{Log}_{10}x$ transformation in Excel 2007. I also transformed TVV and open water data by the same transformation.

In order to determine relationships between physical site measures, I ran a pairwise Pearson’s correlation between open water, TVV and canopy across the 32 sites. I utilized SYSTAT 12.0 (SYSTAT, San Jose, CA) to run stepwise linear regressions of each species calls and total calls against TVV and open water to assess any potential relationships between vegetation data an open water area. For big brown bats (EPFU), northern myotis (MYSE) and silver-haired bats (LANO), I performed a simple linear regression based on species presence/absence distribution across open water and TVV, and canopy data.

Results:

I recorded 4,123 total calls across 32 sites. Calls collected over a total of 13 nights had averaged anywhere between 35 and 526 calls per anabat, per night. The average calls collected per night was 168 (± 47 SE) calls. I detected all six bat species across all sites through Anabat recordings (Table 1). The most common species recorded were little brown bats (81.8% of all calls), hoary bats (10.0% of all calls), and red bats (5.3% of all calls). In addition, of the 15 total bats caught, 11 were little brown bats, 2 were northern myotis, and 2 were silver-haired bats (Table 2).

Across the sites, canopy cover varied from 0.0 - 97.5% cover (17 out of 32 had 0-10% canopy, 6 had 10-40% canopy, 5 had between 40-75% canopy, and 4 had between 75-97.9% cover. Total vegetation volume varied from an average of 0.000714 to 0.024. Open water across sites had a range of 114 - 44,994 m^2 (Appendix 1).

A zero correlation comparison revealed a significant correlation between TVV and percent canopy ($r > 0.999$, $p < 0.001$; Table 4). Likewise, I found significant relationships for both open water and canopy ($r = -0.424$, $p = 0.016$) or TVV and open water area ($r = -0.424$, $p = 0.016$).

Stepwise linear regressions provided statistical significance only for *Myotis lucifugus* (MYLU), *Lasiurus borealis* (LABO), *Lasiurus cinereus* (LACI), and total calls (no distinction between species) per site. A stepwise linear regression revealed an indirect relationship between TVV and MYLU activity based on an adjusted squared multiple R-value of 0.147 (SC = -30.98, SE = 12.31, p = 0.017). A separate stepwise linear regression indicated an indirect relationship between LABO activity and total canopy (R^2 = 0.302, p = 0.001, SC = -48.33, SE = 26.61). I also discovered a direct relationship between LACI activity and area of open water (R^2 value = 0.174, p = 0.007, SC = -2.68, SE = 0.26; Table 3).

Separate linear regressions showed marginally significant negative relationships between total bat activity and TVV (R^2 = 0.155, p = 0.056, SC = -48.33, SE = 24.34), as well as total bat activity and percent canopy (R^2 = 0.155, p = 0.056; Table 3).

Out of the stepwise presence/absence regressions, only one regression showing an indirect relationship between MYSE activity and open water was significant (R^2 = 0.224, p = 0.004, SC = -2.29, SE = 0.73). I did not find any relationships between physical site measures and EPFU or LANO activity (Table 3).

Discussion:

My results indicated that individual species vary in response to different physical characteristics of palustrine sites. While the results showed that little brown bats were not influenced by the physical amount of open water or canopy (Table 3), there existed a negative relationship between little brown bat activity and the vertical distribution clutter, or total vegetation volume. Observed little brown bat activity within these palustrine sites reflect previous findings on the negative effect of clutter on small insectivorous bat activity (Brigham et al. 1997). Similarly, my results indicated that total bat activity was primarily influenced by TVV and percent canopy; however because a vast majority (81.8%) of the calls identified were little brown bat calls (driving trends for total bat activity), and because none of the physical measures had a significant relationship with total bat activity, I could not conclusively determine that activity was influenced by any singular physical effect.

Conversely, vertical clutter did not significantly influence the activity of any other individual species in the region. However, my results revealed a similarly negative relationship between red bats and canopy cover (Table 3). That canopy plays a more prominent role in influencing red bat activity is not consistent with previous findings that larger species of bats, including red bats seem to be influenced most by open water area as a physical site factor (Brooks and Ford 2005).

By contrast, while canopy did not significantly alter the behavior of hoary bats, open water was the primary physical factor influencing activity over palustrine sites (Table 3). These findings are consistent with previous studies (Brigham et al. 2007, Brooks and Ford 2005), who emphasized that large-bodied bats are largely unaffected by both vertical and horizontal clutter, and that bat activity tended to increase with increasing palustrine size respectively.

Conversely, open water negatively affected the presence of northern myotis activity. More explicitly, though northern myotis are present across a spectrum of open water area, the species is more likely to be present in sites where there is less open water. Although previous studies have shown that northern myotis activity is greater in areas of high clutter than in areas of low clutter (Owen et al. 2003), my results indicate that open water and not clutter plays a greater role in northern myotis activity at UNDERC. However, since I did find a correlation between open water and both vertical and horizontal clutter (TVV and canopy respectively) these findings do complement (if indirectly so) my results (Table 4).

Because there were so few calls recorded for silver-haired and big brown bats (together the species only comprised 1.4% of the total calls), no significant relationships between physical site characteristics and activity were observed. Patterns might have been more evident had I selected a larger and perhaps more evenly-distributed spectrum of both open water and habitat clutter.

Overall, my results supported my hypothesis that smaller-bodied species would be present in both areas of high and low clutter. With respect to smaller-bodied bats, however, I concluded that species presence does not necessarily dictate greater or lesser species activity. Indeed I found that although little brown bats are present in areas with less vertical clutter, they exhibit more activity in areas of lower clutter. By contrast, because I found that open water was indirectly related to clutter, I could infer that northern myotis do in fact follow this trend of higher activity in areas of higher clutter. Similarly, though I observed no direct trend in larger-bodied bat activity with respect to clutter, I was able to infer the opposite conclusion with hoary bat activity through this indirect relationship between open water and clutter.

Having observed that different physical characteristics of habitats singularly influence diverse bat species, I would continue this experiment over a longer period of time to collect a larger sample set. I would also attempt to anabat at some of the same sites over multiple nights and average the relative activity in order to determine some kind of consistency of bat activity within each site.

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Table 1. Number of calls by species (see text for species codes) and total calls recorded at 32 sites. Also presented is percent distribution of total calls across all sites. The physical characteristics and the location of these sites by name are found in Appendix 1.

Site name	MYLU	MYSE	LABO	LANO	LACI	EPFU	Total
Beaver Bog	58	0	11	0	0	1	70
Beaverbat	83	0	4	0	34	2	123
Beavergate Bog	64	0	19	0	19	8	110
Boomer Bog	487	7	24	0	8	0	526
Buck Marsh	181	12	13	0	5	0	211
Caketown	119	0	3	0	2	0	124
Castleberry	33	0	2	0	3	0	38
CG	11	0	0	2	81	1	95
Dead Marshes	72	0	2	0	33	1	108
Delicious	33	0	1	0	10	2	46
Donut Bog	41	0	5	0	4	0	50
Donut BP	27	0	6	0	2	0	35
Fern Gully	75	1	1	0	1	1	79
Fitted Briefs	29	3	0	0	13	12	57
Foggy Pond	311	2	22	0	3	1	339
Forest Service Bog	297	1	14	0	1	1	314
Hellenthal	172	1	14	0	1	0	188
Junior Bog	59	0	4	0	33	4	100
Northgate Bog	88	0	11	1	4	4	108
Northwest BP	478	1	23	0	7	5	514
Peyton Pond	8	0	0	0	2	1	11
Pseudonine	58	29	0	0	7	0	94
Reddington	42	0	9	0	16	0	67
Snag Marsh	6	0	0	1	84	0	91
Tender Bog	88	1	3	0	19	2	113
VP 6	9	0	0	1	1	0	11
VP J	185	1	0	0	0	0	186
VP K	21	8	0	0	0	0	29

VP Proximity	37	1	0	0	0	0	38
VP V	12	0	4	0	0	0	16
Ward Crick	68	3	1	0	2	0	74
Total Calls recorded	3397	73	221	7	410	50	4158
Percent of total calls	0.817	0.018	0.053	0.002	0.10	0.012	100

Table 2. Physical data recorded for each bat captured on collection nights. Listed are date of capture, site of capture, species (see text for species codes), gender, age, reproductive condition, weight, forearm size, and whether or not the bat was shaved in the event of recapture.

Date	Site	Species	Sex	Age	Reproductive Condition	Weight (g)	Forearm (mm)	Shaved?
6/13/2007	VPK	MYLU	M	A	Scrotal	5.5	35	No
6/13/2007	VPK	MYLU	M	A	Nonscrotal	7.5	36	No
6/13/2007	VPK	MYLU	M	A	Scrotal	7.8	36	No
6/16/2007	Tender Bog	MYLU	F	A	Nonlactating	8	37	Yes
6/23/2007	Fitted Briefs	MYSE	F	A	Nonlactating	7	37	Yes
6/23/2007	Fitted Briefs	MYLU	M	A	Nonscrotal	8.6	38	Yes
6/24/2007	Willow Marsh	LANO	M	A	Nonscrotal	10.3	40	Yes
6/25/2007	Foggy Bog	MYLU	F	A	Nonlactating	8.6	34	Yes
6/25/2007	Foggy Bog	MYLU	M	A	Nonscrotal	7.8	39	Yes
6/25/2007	Foggy Bog	MYSE	F	A	Nonlactating	7.2	37	Yes
6/25/2007	Foggy Bog	MYLU	M	A	Nonscrotal	9	37	Yes
6/29/2007	Gravel Pit Bog	MYLU	M	A	Nonscrotal	8.8	36	Yes
6/29/2007	Gravel Pit Bog	MYLU	M	A	Nonscrotal	8.8	35	Yes
6/29/2007	Gravel Pit Bog	MYLU	M	A	Scrotal	8.2	36	Yes
6/29/2007	Gravel Pit Bog	LANO	M	A	Scrotal	10.3	42	No

Table 3. Stepwise linear regressions performed for individual species, based on the number of calls recorded across all sites. The regressions performed on the total number of calls were individual regressions. Significant positive or negative relationships indicated with associated multiple R^2 value.

Species	Factor compared	Multiple R^2	Slope Coefficient	Standard Error	p-value
MYLU	TVV	0.211 (negative)	-30.98	12.31	0.006
	Canopy	n/a	1050.72	9397.34	0.912
	Open water	n/a	-0.97	0.841	0.250
MYSE	TVV	n/a	1790.85	3915.18	0.350
	Canopy	n/a	-4198.81	9115.88	0.349
	Open water	0.224 (negative)	-2.29	0.73	0.004
LABO	TVV	n/a	1829.13	3733.79	0.628
	Canopy	0.302 (negative)	-100.97	26.61	0.001
	Open Water	n/a	0.87	0.78	0.257
LANO	TVV	n/a	12.76	9.71	0.199
	Canopy	n/a	-6222.72	7326.66	0.200
	Open Water	n/a	0.74	0.65	0.651
LACI	TVV	n/a	-4439.21	4435.20	0.325
	Canopy	n/a	10389.60	53.25	0.138
	Open Water	0.174 (positive)	2.68	0.26	0.007
EPFU	TVV	n/a	-412.08	6623.42	0.512
	Canopy	n/a	2.25	9.52	0.511
	Open Water	n/a	0.80	0.52	0.329
TOTAL	TVV	0.116 (negative)	-48.33	24.34	0.056
	Canopy	0.116 (negative)	-48.33	24.34	0.056
	Open Water	n/a	n/a	n/a	0.492

Table 4. Zero correlations between physical site measures (r). P-values are depicted in **bold**. A strong linear correlation between percent canopy and total vegetation volume (TVV) was found with a correlation (r > 0.999, p < 0.001). Likewise, correlations were found between open water area and total vegetation volume (p = 0.016), and open water and percent canopy (p = 0.016).

	TVV	% CANOPY	OPEN WATER	TOTAL CALLS
TVV	1.000	**<0.001**	**0.016**	**0.056**
% CANOPY	> 0.999	1.000	**0.016**	**0.411**
OPEN WATER	-0.424	-0.424	1.000	**0.492**
TOTAL CALLS	-0.341	-0.341	0.126	1.000

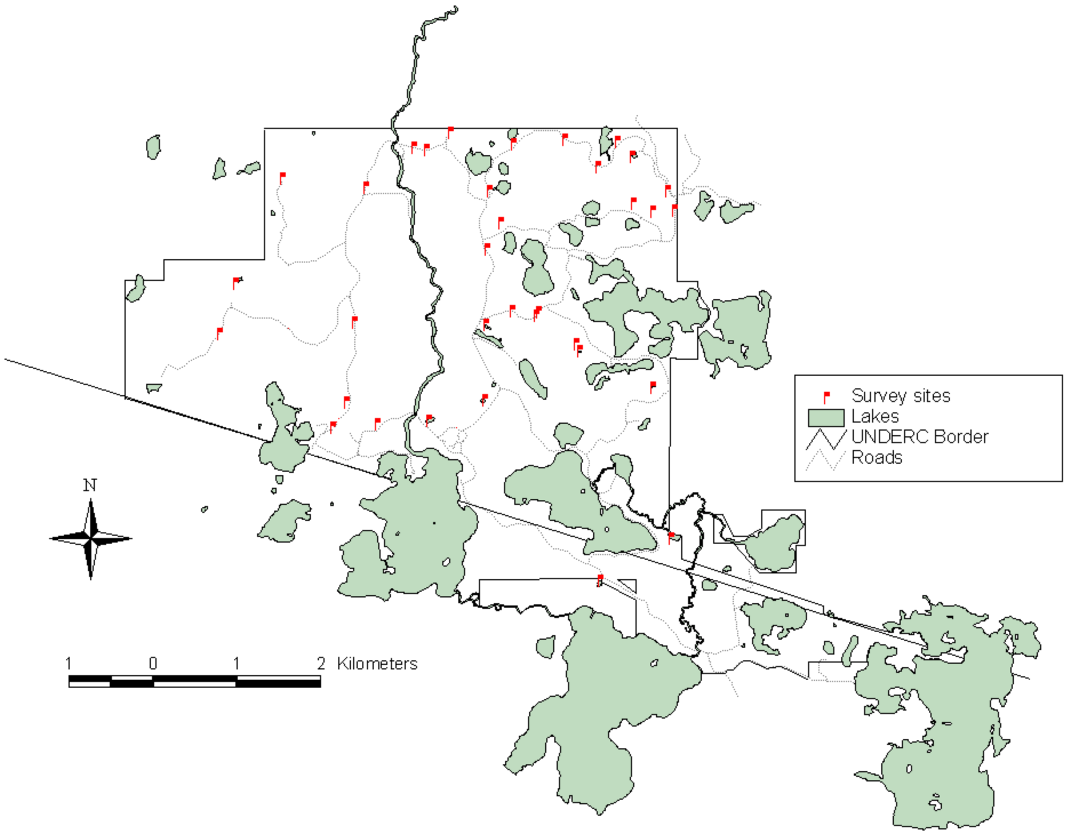

Figure 1. A map of the UNDERC property with anabatting sites marked with red flags (created with Arcview 3.3). All open water areas are denoted by the shaded areas.

Appendix 1. Locality information (UTM NAD27, Zone 16N) and physical measures (area of open water, total vegetation volume [TVV], and percent canopy) for 32 sites surveyed for bats in summer 2007 at UNDERC.

Site name	UTM E	UTM N	Open Water Area (m^2)	TVV	Percent Canopy
Beaver Bog	305788	5123598	1354	0.0025	5.57
Beaverbat Beaver Pond	307749	5124943	9625	0.005	8.68
Beavergate Bog	305361	5125879	44994	0.008929	1.41
Boomer Bog	304229	5123629	206	0.011786	9.41
Buck Marsh	305803	5124498	240	0.008571	7.97
Caketown Bog	304938	5125698	817	0.016786	1.44
Castleberry Bog	307930	5125185	955	0.0175	5.11
Cranberry Grape Marsh	302626	5123490	514	0.016429	21.56
Dead Marshes	307097	5125477	3120	0.005639	11.16
Delicious Beaver Pond	306708	5125800	1810	0.013571	11.17
Donut Beaver Pond	306793	5123355	23507	0.001071	9.5
Donut Bog	306885	5123284	677	0.006071	1.21
Fern Gully Marsh	306084	5123765	128	0.016071	57.88
Fitted Briefs Beaver Pond	307530	5125035	155	0.017857	63.59
Foggy Beaver Pond	308018	5124958	186	0.004286	33.07
Forest Service Bog	307135	5120573	2548	0.001786	0.43
Hellenthal Bog	307976	5121075	8333	0.000714	0
Junior Bog	305777	5122712	1516	0.008929	6.73
North Gate Bog	307509	5125599	2280	0.000714	0.19
NorthWest Beaver Pond	303368	5125334	42315	0.0075	5.43
Peyton Pond	307337	5125769	864	0.022143	31.87
Pseudonine Vernal Pond	304129	5122696	114	0.011429	52.54
Reddington Pond	306103	5125749	11143	0.008571	1.97
Snag Marsh	304499	5122437	15017	0.018571	7.34
Tender Bog	305108	5122480	3918	0.0025	3.57
Vernal Pond 6	303976	5122397	674	0.015714	25.82
Vernal Pond J	306374	5123704	210	0.011071	95.52
Vernal Pond K	306394	5123746	124	0.016429	84.92
Vernal Pond Proximity	305466	5122370	130	0.015	97.48
Vernal Pond V	305945	5124813	377	0.006786	51.03

Ward Creek	305827	5125193	151	0.023929	48.76
Willow Marsh	305088	5125678	479	0.020357	15.18