Final Report

Biotic Diversity of Aspen Stands In RMNP: Effects of Browsing Enclosures

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Introduction

A Composite Biodiversity Study

The study attempts to examine the biodiversity among herbivore enclosures (aspen enclosures) for plants, insects, reptiles, amphibians, mammals, and birds with both student data (a sort of trained citizen science) and faculty that are experts in respective taxa. The study was in coordination with the 2012 Rocky Mountain National Park (RMNP) Bioblitz, but includes sampling in June (an ecology class) and July (paid students) because it is so hard to evaluate biodiversity in one 48 hour period; a period that does not coordinate with the greatest diversity of RMNP. Thus, we devoted the entire lab section of UNC's summer ecology course to this end and an additional sampling in July. The data are thus a combination of morphologically-identified diversity (from 24 students) and taxonomically-identified diversity (grant PIs). This composite study resulted in a unique training opportunity for students and an extended view of the biodiversity of aspen enclosures in RMNP.

Biodiversity

This research has been specifically set up to coordinate with the *Bioblitz* collaboration between Rocky Mountain National Park (RMNP) and National Geographic Society on August 24 and 25, 2012. Bioblitzes are a response to known gaps in knowledge for overall species diversity on public lands and the lack of adequate inventories in US National Parks (Stohlgren et al. 1995). Over the past two decades, forest management and conservation have focused their efforts on: 1) a larger spatial scale of landscapes and regions and 2) ecosystem management, including effects of management decisions on a range of ecological levels and ecosystem processes. The focus on broader spatial and ecological scales necessitates the collection of data on threatened and endangered species, land use, common and rare communities, and the relationships among biotic and abiotic factors (Convoy and Noon 1996; Kaennel 1997; Innes and Koch 1998). Consequently, public and private organizations throughout the world have focused on biotic inventories (e.g., The Gap Analysis Project; Burley 1988; Soberón et al. 1996) that serve as the basis for developing management plans, identifying biological hotspots, predicting available species habitat, and mapping forest productivity (Noss 1987, 1995; Band and Wood 1988; Scott et al. 1993; Allen et al. 1995).

Aspen Forests

Aspen (*Populus tremuloides* Michx.) stands provide a variety of ecosystem services, including soil improvement, watershed protection, wildlife habitat, economic products (mainly pulp), landscape diversity, recreation, and an atmospheric CO_2 sink, (St. Clair et al. 2010). Researchers have suggested since the 1940s that aspen stands were declining in the western United States (Gallant et al. 2003) due mainly to suppression of fire and widespread herbivory (Suzuki et al. 1999, Jones et al. 2005, Kaye et al. 2005). More recently, the hastened loss of overstory trees

(Sudden Aspen Decline, SAD) suggests drought as a factor (Worrall et al. 2008). Studies of specific areas in the west are confounded: some found the majority of aspen stands were in decline and significant areas of aspen cover have been lost over the past century while others suggest aspen is increasing or persistent (Table 1). Recent work strongly suggests aspen decline is both spatially and temporally variable and depends on site characteristics, disturbance, succession to conifer forests, extreme climatic events (drought and anomalous cool, moist years), and herbivory; all are influenced by humans (St. Clair et al. 2010). At least one of the aspen-dominated communities (*Populus tremuloides*/*Acer glabrum* Forest) is ranked as a G1G2 (globally imperiled) and S2 (State imperiled) community. Several others communities dominated by aspen are ranked as vulnerable.

Table 1: Evidence for the stability, decline, and increase in aspen at the landscape scale in the North America.

Publication	Location	Range of Study	Aspen Change
Stand Structure and Tree Ring Data			
Romme et al. 1995	Yellowstone National Park, WY	1820-1990	Declining
Ripple & Larsen 2000	Yellowstone National Park, WY	1750-1980	Declining
Romme et al. 2001	San Juan Mountains, CO	1865-2000	Persistent
Hessl & Graumlich 2002	Bridger-Teton National Forest area, WY	1830-1897	Persistent
Moore & Huffman 2004	Grand Canyon National Park, NV	18??-20??	Increasing
Kaye et al. 2005	Rocky Mountain National Park area, CO	1871-2000	Persistent
Kashian et al. 2007	Northern CO Front Range	1890-2000	Slight decline
Kurzel et al. 2007	Northwestern Colorado	1750-2000	Persistent
Binkley 2008	Rocky Mountain National Park, CO	1860-1960	Increasing
Sankey 2008	Centennial Valley, MT	1850-2000	Persistent
Rogers et al. 2009	Southern Utah	2008	Persistent
Sankey 2012	Reynolds Creek Exp. Watershed, Southwestern ID	1965-2008	Spatially variable
Current Regeneration Used to Assess Long-term Persistence			
Packard 1942	Rocky Mountain National Park, CO	1939-1940	Declining
Baker et al. 1997	Rocky Mountain National Park, CO	1997	Declining
Suzuki et al. 1999	Rocky Mountain National Park and Arapahoe Roosevelt National Forest, CO	1999	Persistent
Barnett and Stohlgren 2001	Grand Teton National Park, WY	2000	Persistent
Repeat Photography			
Manier & Laven 2002	Western Slope, Rocky Mountains	1896-1995	Increased
Elliot and Baker 2004	San Juan Mountains, CO	1875-2002	Increasing
Zier & Baker 2006	San Juan Mountains, CO	1871-2004	Increasing
Long-term Resampling of Plots			
Crawford et al. 1998	Crested Butte, CO	1964-1994	Persistent
Kay 2001	Greater Yellowstone Ecosystem, WY	1934-1996	Persistent
Smith and Smith 2005	Uncompahgre Plateau, CO	1979-1998	Declining
Cover Map and Aerial Photo Comparison			
Kulakowski et al. 2004	Grand Mesa Area, CO	1898-1998	Increasing
Di Orio et al. 2005	South Warner Mountains, CA	1946-1994	Declining
Kulakowski et al. 2006	Flat Tops, CO	1898-1998	Persistent
Models of Forest Dynamics			
Gallant et al. 2003	Beaver Creek, ID	1856-1996	Declining

Herbivory directly affects aspen stand reproduction (Baker et al. 1997; Weisberg and Coughenour 2003; Binkley 2008). Herbivory affects suckering, as loss of apical dominance leads to increased sucker density, albeit not necessarily survival (Perala 2000), and herbivory has the potential to entirely negate any aspen regeneration (Romme et al. 2005, Sankey et al. 2005). Because suckering is the main regeneration strategy for aspen in Colorado, it is important to understand how this regeneration strategy works (St. Clair et al. 2010) and how important it is in regard to restoration management and maintenance of aspen stands. Because aspen provide many ecosystem services, it is likely that browsing has cascading effects on other trophic levels. Indeed, studies examining elk exclosures have shown effects on butterfly (Beever et al. 2005) and bird (Martin and Maron 2012) populations in relation to flora changes.

Study Objectives

The objectives of the study were to produce qualitative and quantitative data on the biodiversity (plants, insects, herps, birds, and mammals) of herbivore enclosures of aspen stands and compare that data to areas still under browsing pressure. Three treatments were examined: 1) enclosures built in the early 1960s, 2) enclosures built in 2009, and areas adjacent to enclosures built in 2009 (controls). We sampled in June, July, and August to capture seasonal changes and a better estimate of overall diversity. The expectation was that community composition in areas excluded from browsing would be different and generally higher in diversity than areas with browsing. A secondary objective was to involve a class in a holistic ecological examination of a specific area; a combination of place-based and citizen science. This process sacrificed quality of data; students could not identify taxa from all tropic levels to species but instead relied on morphospecies techniques. Thus, we attempt to clearly define student-collected versus PI-collected data throughout the report; it should be noted that the morphospecies techniques have known pitfalls and generally underestimate diversity (Derraik et al. 2010). We use the morphological data here in a relative sense among treatments.

Methods

Site Location

Two areas were chosen in Rocky Mountain National Park: Upper Beaver Meadows (40º22’21.56” N, 105º36’50.07” W) and Fern Lake Road (40º21’23.59”, 105º37’22.48”; Fig. 1). The Upper Beaver Meadows site had aspen stands in three enclosure: two built in the 1960s (areas = 1.23 ha and 0.42 ha) and one built in 2009 (area = 0.99 ha; Fig. 2). The Fern Lake Road site had an enclosure built in 2009 (area = 3.59 ha; Fig. 3). Two Aspen stands adjacent to the recently built enclosures, but outside enclosures, were used as control sites. To help standardize the results, specific areas were used for each collection of data and were maintained in all enclosures and control sites. The study design allows for the comparison of short-term changes to enclosures (data from the 2009 enclosure and data from an adjacent aspen stand not exclosed) and long-term effects of enclosures (data from 1960s enclosures) on the biotic community (three treatments, n=2; N=6). It should be noted that the 2009 enclosures are for larger animals only due to a 16 inch (41 cm) gap between the ground and fence (Gage and Cooper 2008), while the 1960s enclosures are fenced to the ground (although even these enclosures had sections of fence that would not exclude mesopredators). The two areas shared similar elevation and nearness to lentic systems, but the Moraine Park area also contained rock ledges just across a road.

Figure 1. Approximate locations (outlined in blue) of the Upper Beaver Meadows enclosures and Fern Lake Road enclosure for the RMNP Bioblitz research.

Figure 2. Approximate location of Upper Beavers Meadow enclosure (blue outline; 2009) and locations of two older enclosures (1960s) easily seen from 2004 Google satellite images.

Figure 3. Approximate location of Fern Lake road enclosure (2009).

Enclosure Sampling

Field Sampling

We followed the CVS protocol (Peet) using 10 m X 10 m plots, sampling all strata layers of vegetation at multiple spatial scales. At least two plots were placed in each enclosure. In addition, the full area of all six sites was scoured for additional taxa that did not occur in the plots. Both vascular and nonvascular species were included in data collection and determining presence.

In addition to the vegetation sampling, four soil samples, one from each approximate quadrant, were collected in July and sent to A&L Ag Laboratories for analysis of exchangeable nutrients, organic matter, cation exchange capacity, and pH.

Insects were collected by random sweeps (for arboreal insects) and twenty pint-sized mason jar pitfalls (for ground insects); jars were placed at 2 m intervals along two 20 m transects randomly placed in each site. Random sweeps occurred for 30 minutes and all insects were recorded by count and photographed for identification. Insects were released after capture. In addition, dusk-to-evening samples were collected using light traps and sheets.

Birds were sampled using a point count method in June and August. Since sites were small, only one legitimate point count was possible. Each point count was a combination of two mornings, spending 15 minutes per site and randomly choosing one of two points within the site (one point sampled each day). Two observers conducted all point counts simultaneously. Mist netting occurred during the August sampling. Nets were set up inside and outside the 2009 enclosure in Upper Beaver Meadows for two days. Any nesting was also identified and logged.

Herpetological fauna were examined using a modified Jones array drift fence; one per site. The Jones array consisted of four five-gallon buckets with 2.5 m of drift fence between. The Jones arrays were opened at dusk for three nights in June and July, and for two nights in August and checked immediately in the morning. All animals were photographed and released.

For small mammals, 17-20 Sherman live traps were set up at each site for 48 hours in June, July and August; bait was oats and traps were checked every few hours until 10 pm and first thing every morning. Some small mammals were collected in the Jones array as well. Unknown animals were photographed and released.

For bats, a sonar system will be set up in June (one night) and August (two nights) to collect calls and determine species diversity from those calls.

For all above animal collecting, the rules of the NPS and animal collecting were followed. Any accidental deaths were properly disposed. A few shrews were kept for another study (examining larynx development) based on a verbal agreement with Jeff Connor.

Photo Sampling

Due to the limited amount of time available to spend on site and the mobility and temporal dynamics of biotic populations, we placed a time-lapse and a motion-activated camera on each of the six sites. The motion-activated cameras were meant to capture the use of the aspen stands by animals and the time-lapse cameras were meant to capture the phenology of the site and sporadic growth periods (flowering, fungal body growth). Time-lapse cameras were placed on aspen stems approximately 0.5 m from the ground and took a picture every 24 hours at 11 am MST. Motion-activated cameras were placed approximately 1.5 m from the ground. Cameras will be checked and data downloaded every few weeks.

Analysis

The following provide a descriptive comparative analysis among the treatments (new enclosure, old enclosure, no enclosure). Count data were used to compare sites and calculate diversity indices. In addition, species lists for several taxa were developed for all sites. Differences in diversity and taxa were used to assess the effects of browse enclosures.

Results

Soils

Soil characteristics did not show large differences among recent enclosures and their adjacent browsed control sites. If anything, control sites are higher in nutrient pools, organic matter, and cation exchange capacity (Fig. 4). However, soil nutrient quality was clearly elevated in older aspen enclosures.

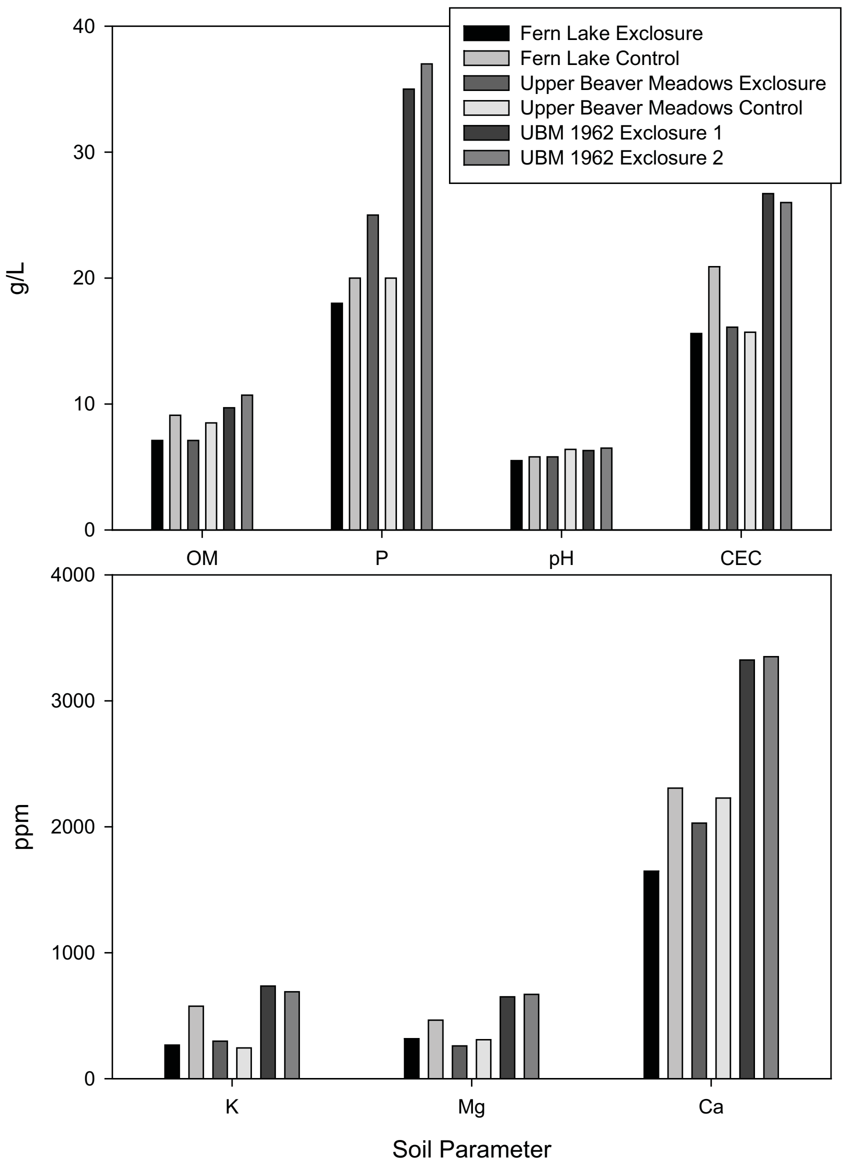

Figure 4. Soil characteristics for recent and older enclosures and adjacent control aspen stands.

Plants

Student-collected plant diversity data suggested slightly higher diversity in control plots adjacent to recent enclosures. However, PI-collected data showed that the Upper Beaver Meadows recent enclosure and adjacent control site had the greatest diversity while the older enclosures less than a mile away had the least diversity (Fig. 5). It is also clear, as expected, that student-collected diversity underestimated site diversity, especially in high diversity sites. Based on these data, there was no evidence that recent enclosures affected diversity. However, long-term enclosures may indeed decrease plant diversity of aspen stands. It was also evident that 2009 enclosures already had a significantly different vertical structure to their community, with vegetation growing higher and cover at the soil surface decreasing (Fig. 6).

Upon review of the time-series photography, we found no differences in the phenology of enclosed and control aspen stands. Leaf out started on May 4 and the vegetation was fully flushed by May 20. Spring wildflowers started blooming in late May and lasted most of June. Grass flowering was restricted to August. Fall colors started on September 4 and most leaves had dropped by Oct. 1.

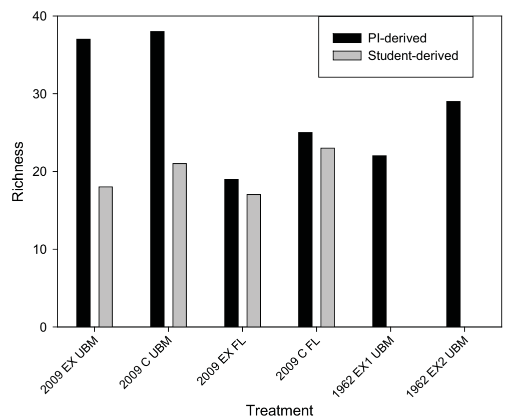

Figure 5. Student and PI-collected plant diversity data based on one 10X10 m module.

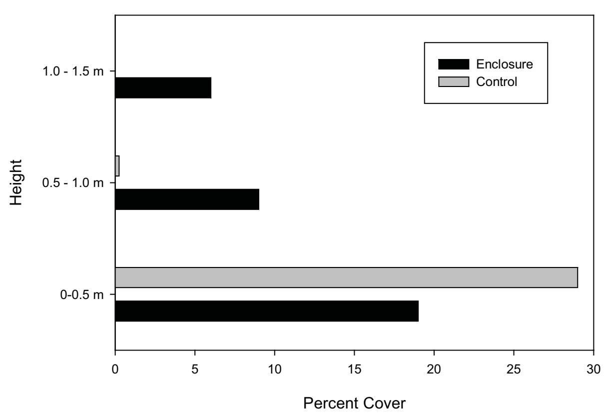

Fig. 6. Average percent cover at three vertical levels above soil surface for sites inside 2009 enclosures and adjacent browsed control sites.

Insects

We did not have an expert for invertebrates except for aquatic macroinvertebrates, so all of the data are based on morphospecies. Neither richness nor total counts suggest a treatment effects, although if may be worth noting that the older enclosures had both a higher richness of insects and a greater abundance of butterflies (Fig. 7). Contrary to richness, taxa appear different based on treatments, with spider abundance much greater in enclosure plots (Fig. 8).

Stream macroinvertebrates were rich both inside and outside of the enclosure, totaling 10 separate taxa. Communities were a bit different, albeit dominated by stone flies in riffles and pools and inside and outside the enclosure. Contrary to the similarity of macroinvertebrates, both temperature and conductivity were slightly higher inside the enclosure (Fig. 10).

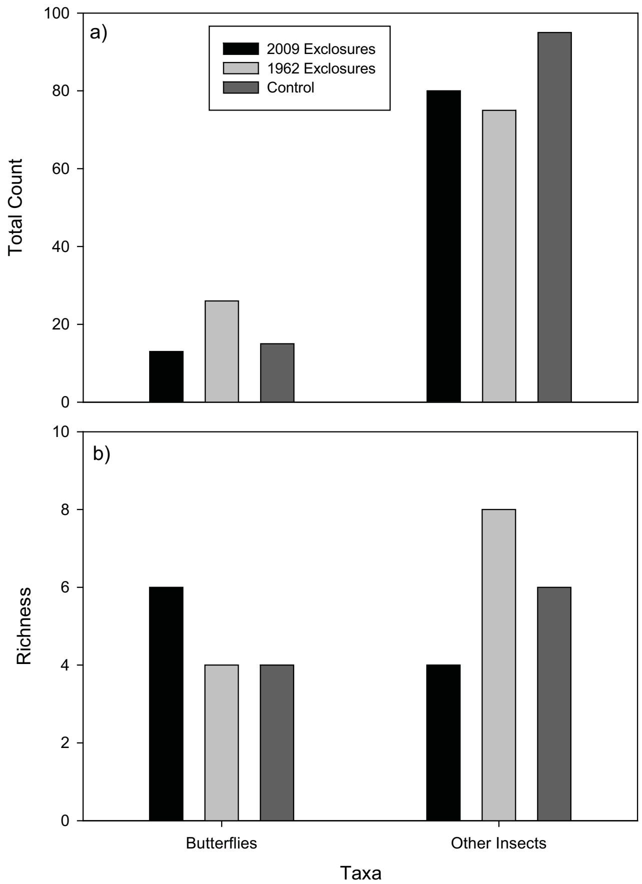

Fig. 7. Insect density (b) and richness (a) and based on time counts (butterflies) and pitfall traps (all other insects).

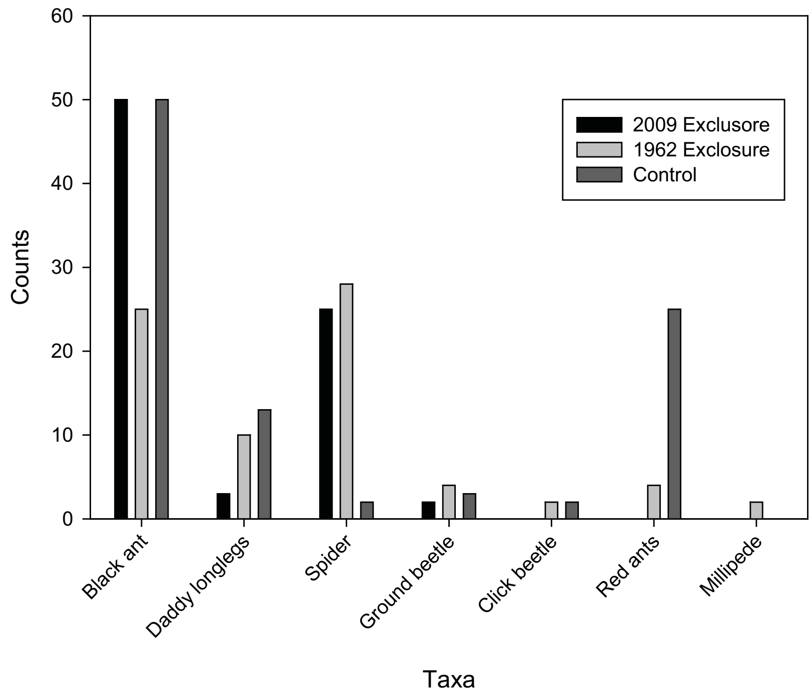

Fig. 8. Total counts of insect taxa from pitfalls by treatment.

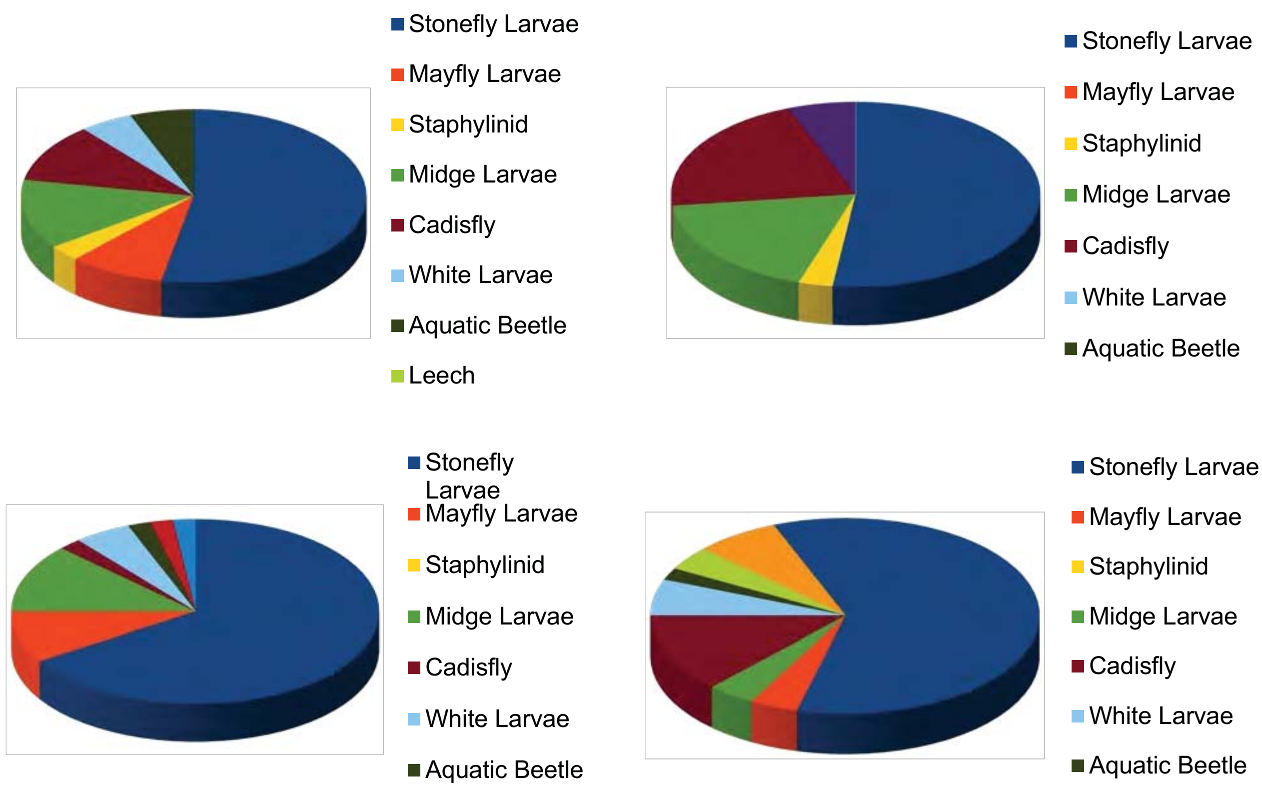

Figure 9. Aquatic macroinvertebrates as assessed by morphospecies in June both inside and outside of the Upper Beaver Meadows enclosure.

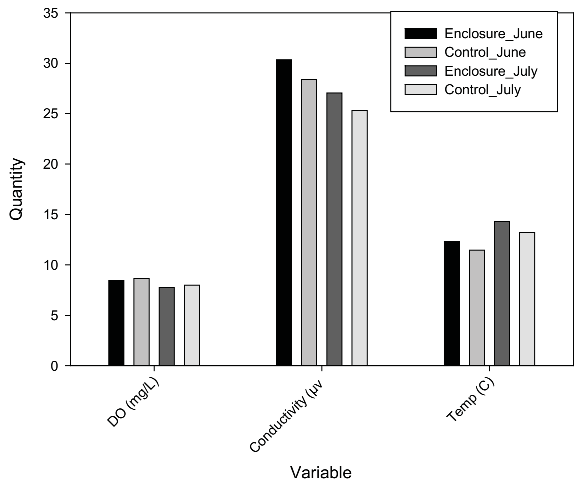

Fig. 10. Stream dissolved oxygen, conductivity, and temperature in June and July at the Upper Beaver Meadows site; inside and outside of enclosure.

Herpetofauna

Despite an extended effort to document herpetofauna in these stands, only one herp was caught the entire sampling season; a western garter snake. It was caught in the Jones array of one of the 1962 enclosures.

Birds

No treatment effect was apparent based on the richness of birds (Fig. 11). Student-collected data were noticeably lower than PI-collected data for the Fern Lake sites, both enclosure and control. However, these data were collected in June by students and in August by PIs, so the different months may explain the difference. It may be likely that birds increased around the river during the very dry summer; the river was only 200 m from the FL sites. Meanwhile, the small tributary creek running through the Upper Beaver Meadows site was down to a trickle. Total number of sitings was much higher for PIs, likely due to their ability to identify song. In addition to these sitings, we found nesters in the enclosures, both 2009 (broadtail hummingbird, greenback swallow, pygmy nuthatch, and house wren) and 1962 (kingbird).

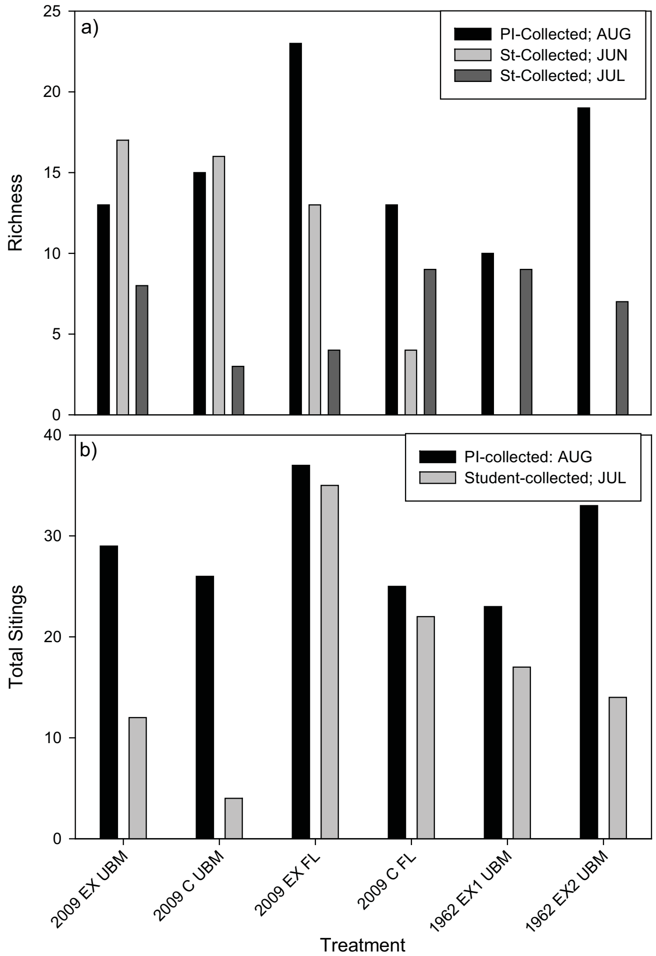

Fig. 11. Bird richness (a, based on both sites and calls) and total sitings (b) based on student-collected (June/July) and PI-collected (August) point counts over two mornings each.

Mammals

The diversity of small mammals was unaffected by enclosures. We essentially found the same species within enclosures and outside in adjacent control sites. The number of small mammals was apparently affected by enclosures, but effects were specific to mice (Fig. 12); mice were much more abundant in enclosures, both recent and older. Species included the deer mouse (*Peromyscus maniculatus*), long-tailed vole (*Microtus longicaudus*), shrew (*Sorex* sp.), and meadow jumping mouse (*Zapus hudsonius*).

Sonar data suggested four bat species near the enclosure sites, but none were for certain within the enclosures: Hoary Bat (*Lasiurus cinereus*), Big Brown Bat (*Eptesicus fuscus*), Little Brown Bat (*Myotis lucifugus*), and Silver-haired Bat (*Lasionycteris noctivagans*).

Animal use based on camera data was clearly affected by enclosures with only three mule deer (*Odocoileus hemionus*) witnessed the entire season; humans showed approximately the same use both in and out of enclosures. Animal use clearly favored day hours (Fig. 13) with moose (*Alces alces*) perhaps being an exception (too few data to truly tell). In addition to the animals caught on cameras, we witnessed black bear (*Ursus americanus*) and rabbits (*Sylvilagus nuttallii*) both within and outside enclosures and coyotes outside enclosures.

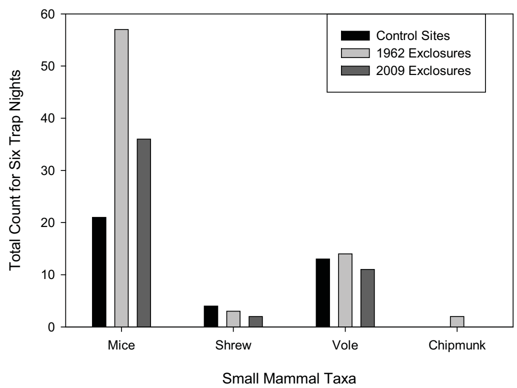

Fig. 12. Total number of small mammal species caught over six trap nights in summer 2012.

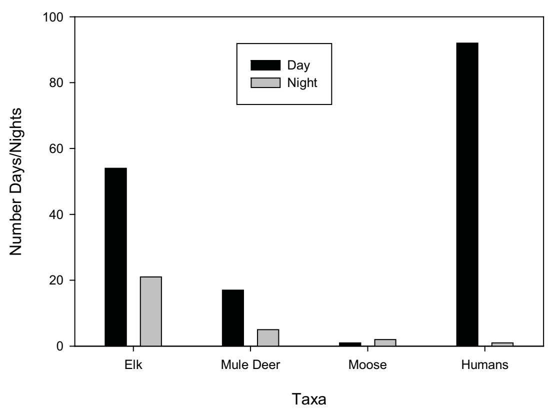

Fig. 13. Number of days or nights witnessing visitation by various ungulate taxa.

Discussion

Biodiversity Aspect

In general, the data do not support our hypothesis that enclosed aspen stands would have higher biodiversity than control stands, but there are two reasons for further study. First, the data were collected only three years following the building of the enclosures and clearly our data as well as Gage and Cooper (2008) showed such enclosures affect large animal movement. Second, short–term impacts have been seen at other enclosures studies (Kleintjes Neff et al. 2007), and our results (trend toward higher diversity in aspen enclosures) support their results.

Two trends are clear from the above data. First, there was a noticeable alteration to the vertical structure of vegetation and such changes in structure are known to have cascading effects on other trophic levels (Kleintjes Neff et al. 2007). Second, soil chemistry is very different between enclosed and control sites, especially those enclosures that are 50 years old. This result alone supports a functional change to these stands when released from heavy browsing pressure. While impacts on richness were not yet clear, there is certainly reason to believe biodiversity may be affected in a longer time frame.

Citizen Science Aspect

Base on the general take-home messages, students' data seemed to suggest the same trends as PI-collected data, so that seems a positive result for citizen science. Such a result suggests citizens can be trained in a short period of time for morphospecies monitoring and that data would be useful. While PI-collected and student-collected data are not directly comparable due to time differences, student-collected data generally underestimated biodiversity as has been shown in other studies (Derraik et al. 2010), mainly due to a lack of identification skills and not necessarily a lack of 'seeing' individuals. One particular component is bird calls that are extremely difficult to teach to a novice.

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