Harvest Sustainability Study of Wild Populations of Osha, *Ligusticum porteri*

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Cover photo: A large osha rhizome, harvested from an old osha crown in the Meadow site, near Cumbres Pass, Rio Grande National Forest in southern Colorado, August 2012.

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Abstract

Osha (*Ligusticum porteri* J.M. Coult. & Rose) is an ethnobotanically important medicinal plant whose pungent and distinctively spicy roots are wild harvested by individuals and sold by herbal product companies to treat influenza, bronchitis, and sore throat, and by Native people as a ceremonial and medicinal plant.

We initiated a multi-year manipulative field experiment to determine acceptable thresholds of harvest intensity that allow for the regeneration and sustainable harvest of populations.

We also determined population densities of geographically separated populations by sampling vegetative cover of osha within 8 mapped stands. These sampled stands had a cumulative area of 507,597m^2, with an average of 7.8% osha cover.

For our manipulative field experiment analyzing osha's recovery from harvest, we established experimental plots in both a Meadow site with high light availability, and in an adjacent Forested site with substantial canopy cover. At both sites we established 40 replicate 30m^2 plots, collected data on vegetative cover, and harvested roots at intensities alternating sequentially between 0%, 33%, 66%, or 100% of mature plants in each plot.

The Meadow site had 15% more mature plants and 58% more root mass than the Forested site. From our data we estimate that a meadow population exhibiting a 10% cover (a dense stand) will have on average 52.2 g dried root weight per 1 m^2 area (465 lbs/acre), while a forest population exhibiting a 9% cover will have on average 13.7 g dried root weight per 1m^2 area (122 lbs/acre).

Baseline data were successfully gathered and, with additional funding, post-harvest regrowth data will be collected through monitoring efforts in subsequent years. These data will help to determine sustainable rates of harvest and inform conservation measures needed to ensure the long-term viability of this species.

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Introduction

Ligusticum porteri is commonly known as osha, bear root, and *chuchupate* in Spanish. It is a slow growing, perennial member of the Parsley family and, according to herbarium specimen data, occurs in high elevation sites ranging from 6,000—11,700 feet (1829—3567 m). It thrives in diverse soil types, and is often found nearby or within groves of aspen, conifers, fir, and oak (Cech 2002; Moore 2003; Scientific Authority of the United States of America 2000; Turi and Murch 2010). Its range is distributed throughout the Rocky Mountains, spanning Montana and Wyoming in the north, through Colorado, Nevada, and Utah, to New Mexico, Arizona, and significantly south into Mexico (Scientific Authority of the United States of America 2000; Terrell and Fennell 2009; Turi and Murch 2010).

Ethnobotany of Osha:

The most important use of osha is the use of its harvested roots for medicine. Large roots, typically from plants at least ten years old, are favored for medicinal harvest (Scientific Authority of the United States of America 2000; Turi and Murch 2010). Osha is known as "bear root," because it is traditionally thought that Native Americans learned of its use by observing bears dig up roots to eat as food. Plants that have their origins as bear medicine are highly respected and considered to be "strong, protective, nurturing, and healing" (Terrell and Fennell 2009). In addition, bears have been observed to rub their fur with osha root apparently to repel insects and soothe bites (Andrews 2005; Costa-Neto 2012). As a medicine, Native Americans historically used the roots to treat a broad array of medical ailments. Currently, the roots are commercially wild-harvested to treat bronchitis, influenza, and other respiratory problems (West and Jackson 2004). Depending on the ailment and area treated, the roots may be used to make a dressing, paste, or liniment; made into an ointment; made into tea or a tincture; chewed; and even burned to clear the sinuses and relieve headaches (Terrell and Fennell 2009). Table 1 lists the medicinal uses of *L. porteri*.

While osha's primary use is medicinal, the leaves, and to a lesser extent the seeds and roots, are also used for food. Osha produces a flavor described as "chervil-celery-parsley flavor" (Turi and Murch 2010) or a "pungent cross of flavors reminiscent of celery and licorice" (Terrell and Fennell 2009). The leaves, seeds, and roots are used to season meat, beans, and chili (Moore 2003; Scientific Authority of the United States of America 2000; Turi and Murch 2010). Leaves can also be boiled and eaten like greens or added raw to salads (Moore 2003; Moerman 2012; Terrell and Fennell 2009; Turi and Murch 2010), and the roots are boiled for use in salads and soups or eaten raw (Turi and Murch 2010).

Medicinal Use	Treatment Details
Colds; Flu; Viral infections	Used to remedy viral infections by inducing sweating and eliminating toxins.
Cough	
Respiratory: Bronchitis	Used at first sign of flu to prevent a viral infection
Tuberculosis	
Sore throat	Crushed root and water used as wash and taken for sore throat.
Fever	One is bathed in an infusion of the roots
Sinus Infections	Burned and the smoke inhaled deeply through the nose to relieve headache and to eliminate sinus infections
Wounds; Bruises	Infusion of root used for body aches.
Skin and ear infections	
Headaches	Used to lessen effects of high altitude, including regulation of pulse rate and less headache.
Diaphoretic (promotes sweating)	Used to induce sweating and eliminate toxins.
Gastrointestinal: Indigestion	
Antiemetic (stops vomiting)	In combination with other plants used for indigestion and recuperation from vomiting.
Anti-rheumatic	Infusion of root used for body aches. Salves and plasters of the roots are applied to joints to alleviate pain associated with rheumatism.
Analgesic	
Heart problems/anti-coagulant	
Poor Circulation	
Diabetes	
Topical insecticide/anti-parasitic/antibacterial	The powdered root is applied in a gauze to prevent infection
Rattlesnakes	Roots used to ward off rattlesnakes
Altitude sickness	Used to lessen effects of high altitude, including regulation of pulse rate and less headache.

Table 1: Medicinal Uses of *Ligusticum porteri*. Osha has been used by the Apache, Navaho, Utes, Zuni, other Pueblo tribes, Lakota, and Hispanic people. This information is sourced from: Moerman 2012; Moore 2003; Curtin, L.S.M. 1976; Camazine, S. and R.A. Bye 1980; Castetter, E.F. and M.E. Opler 1936; and Bye 1986.

Chemical Properties:

The list of medicinally-active compounds in *L. porteri* includes coumarins, phthalides, flavonoids, acetylenic coumpounds, and terpenoids (Bye 1986; Rivero, Juarez, Zuluga, et al. 2012; Turi and Murch 2010). Two of the major active phthalides in *L. porteri* are Z-Ligustilide and Z-6,6′,7,3′-α-diligustilide, however one study identified 31 chemical constituents in the volatile compounds of the roots. The largest percentage of the bioactive components in the essential oils were phthalides (44.61%) and sesquiterpenes (10.69%), and the major light volatile components were monoterpenes (Rivero, et al. 2012). When root extract was administered to mice it produced significant analgesic effects detected by the writhing test (Deciga-Campos 2005). More recently, (Z)-6,6',7,3α –diligustilide, (Z)-ligustilide, 3-(Z)-butylidenephthalide, myristicin, and ferulic acid extracts from the roots of *L. porteri* showed significant hypoglycemic and anti-hyperglycemic effects in mice (Brindis, Rodriguez, Bye, and Mata 2011), providing scientific support for the use of *L. porteri* in diabetes treatment.

Use as an Herbal Product:

At present, one pound of dried osha root can be purchased on the internet at a price anywhere between $27-79 (see Table 2). This range exhibits a high variability in the valuation of osha, even though use patterns have remained steady at a slight incline for the past decade (American Herbal Products Association 2007, 2012; Turi and Murch 2010). The roots have been used in the United States, Japan, and Germany, and included in more than a dozen patent medicines (Burns, Bye, Felger, et al. 1994). In 2010, the aggregate harvest of osha was 2,853 lbs of dried root and 1,942 lbs of fresh root (American Herbal Products Association 2012). We were able to identify at least 40 companies that sell osha products in various forms including: whole dried or fresh root, root tincture, liquid herbal extract, capsules, or root powder (Table 2).

Vendors	Product	Retail Price	Source
Azure Green	1lb. Osha Root Whole	$71.95	
Frontier Natural Products Co-op	1lb. Osha Root Whole	$57.50	
Herbie's Herbs	1lb. Osha Root Whole	$78.75	
Matoska Trading Company	1lb. Osha Root Whole	$36.00	
Monterey Bay Spice Company	1lb. Osha Root Whole	$27.00	Wildcrafted
Mountan Rose Herbs	1lb. Osha Root Whole	$36.00	Wildcrafted
Native Scents	1lb. Osha Root Whole	$39.99	Wildcrafted
Starwest Botanicals	1lb. Osha Root Whole	$47.75	
Taos Herb Co.	1lb. Osha Root Whole	$42.56	Wildcrafted
Wilderness Family Naturals	1lb. Osha Root Cut	$32.76	Wildcrafted
Starwest Botanicals	1lb Osha Root Powder	$59.08	
San Juan Mountains Osha Preserve	Fresh and Dried Roots		Wildcrafted
Bouncing Bear Botanicals	2oz. Osha Root Whole	$9.00	
Herbalfire	2oz. Osha Root Whole	$9.00	
Enerhealth Botanicals	2oz. Osha Root Tincture	$15.99	Wildcrafted
Herbalist-alchemist	2oz. Liquid Herbal Extract	$22.10	Wildcrafted
Shining Mountain Herbs	2oz. Liquid Herbal Extract	$18.99	
Wise Woman Herbals	2oz. Liquid Herbal Extract	$22.80	Wildcrafted
Crystal Buffalo	1.5oz. Osha Root	$20.00	
Celebration Herbals	1oz. Osha Root Whole		Wildcrafted
Healingifts	1oz. Osha Root Whole	$5.00	
Herbs & Arts	1oz. Osha Root Whole	$4.29	Wildcrafted
Meridian Botanicals	1oz. Osha Root Whole	$5.00	Wildcrafted
Orrs Trading Company	1oz. Osha Root Whole	$5.00	
Phoenix Herb Company	1oz. Osha Root Whole	$6.00	
The Wandering Bull	1oz. Osha Root Whole	$6.95	
Backyard Remedies	1oz. Osha Root Tincture	$11.98	Wildcrafted
Elk Mountain Herbs	1oz. Osha Root Tincture	$10.95	Cultivated
Mountain Rose Herbs	1oz. Osha Root Extract	$9.50	Wildcrafted
Natural Wellbeing	1oz. Osha Root Extract	$13.95	Wildcrafted
Nature's Answer	1oz. Osha Root Extract	$13.99	
Starwest Botanicals	1oz. Osha Root Extract	$7.50	
Taos Herb Co.	1oz. Osha Root Extract	$9.50	Wildcrafted
Wind River Herbs	1oz. Osha Root Extract	$13.43	
Gaia Herbs	1oz. Osha Root Extract	$11.99	Wildcrafted
Herb-pharm	1oz. Osha Root Extract	$12.50	Wildcrafted
Herbs. Etc.	1oz. Osha Root Extract	$12.48	
Mountain Rose Herbs	100 Osha Root Capsules	$11.00	Wildcrafted
Sioux Trading Post	0.5oz. Osha Root Whole	$2.50	Wildcrafted

Table 2*:* Retail osha products currently available through the online marketplace.

Harvesting Pressures and Further Research:

The majority of osha harvested is from the wild, which has prompted research on cultivating it, specifically on germinating osha from seed and demonstrating successful propagation from vegetative crown cuttings (Panter, Ashley, Guernsey, et al. 2004; see also Cech 2000; Cech 2002; Turi and Murch 2010; and Terrell and Fennell 2009). Osha as an agricultural crop could be a niche market, with a conservative estimate of a potential retail market of over $10,000,000 (Guernsey 2005); however, even the most thorough study on osha propagation to date indicates a high degree of difficulty in producing osha on a large scale. The costs of establishment years have been shown to outweigh the returns in producing years, and these negative net returns may persist even after fifteen years (Guernsey 2005). As it stands, commercially grown osha is not economically viable in the long run. The growing market demand and potentially shrinking natural supply imply that research into sustainable wild harvest practices is prudent.

Given the difficulties of cultivating osha, the wildcrafting of its roots from older plants, and consumer demand for its medicinal qualities, many have expressed concerns of over-harvest (McKeon 1999; Scientific Authority of the United States of America 2000; West and Jackson 2004). While *L. porteri* was proposed for inclusion in Appendix II of the CITES (Cech 2002; Scientific Authority of the United States of America 2000), it has yet to be listed as a species requiring export controls (CITES 2012). However, *L. porteri* is listed as a species at risk of over-harvest by the United Plant Savers (United Plant Savers 2012). The belief that osha populations are declining is difficult to prove, as populations are not currently tracked by any state or federal conservation because it is relatively common where it is found. But it is only found in a limited range at moist sites in the southern Rocky Mountains and Sierra Madre between 7,000 and 11,000 feet. Additionally, there are no comprehensive management strategies in place for the conservation of this species.

In addition to harvest threats, osha populations can be influenced by habitat disturbances such as tree die off, heavy grazing, and climate change (Scientific Authority of the United States 2000; Julander 1968). In order to determine if osha populations require conservation measures, there is an expressed need for monitoring of populations and more research into osha propagation and sustainable harvesting practices (McKeon 1999; San Juan Public Lands Center 2007; Scientific Authority of the United States of America 2000; Terrell and Fennell 2009; West and Jackson 2004). In response, a collaborative effort between the University of Kansas, the Missouri Botanical Garden, and the U.S. Forest Service, with funding from the American Herbal Products Association and the U.S. Forest Service, has been developed to study populations of osha and assess the sustainability of osha root harvesting for the natural products industry. And this work had the benefit of previous work by the Denver Botanical Garden and Trish Flaster of Botanical Liaisons (Denver Botanic Garden 2005), funded by the US Fish and Wildlife Service, but their work was not completed.

Field Methods

Given the extensive range of osha throughout much of the southern Rocky Mountains, we focused our population mapping efforts in southern Colorado. To create a more thorough compilation of osha localities than presently exists, we acquired and geo-referenced data from herbarium voucher specimens, research literature, the Global Biodiversity Information Facility (GBIF), and state natural heritage databases (Table 3, Figure 1).

Data Source	Website
University of Kansas Herbarium	https:// http://digirportal.biodiversity.ku.edu
Rocky Mountain Herbarium	http://www.rmh.uwyo.edu/data/datapolicy.php
Southwest Environmental Information Network	http://swbiodiversity.org/seinet/misc/usagepolicy.php
Global Biodiversity Information Facility	http://data.gbif.org/
Smithsonian National Museum of Natural History	http://www.mnh.si.edu/rc/db/2data_access_policy.html
Missouri Botanical Garden Tropicos Database	http://www.tropicos.org/TermsOfUse.aspx
Consortium of Pacific Northwest Herbaria	http://www.pnwherbaria.org/data/datausagepolicy.php
New Mexico Biodiversity Collections Consortium	http://nmbiodiversity.org/fineprint.php
NYBG: The C. V. Starr Virtual Herbarium	http://sciweb.nybg.org/science2/VirtualHerbarium.asp
University of Oklahoma Rober Bebb Herbarium	http://www.biosurvey.ou.edu/bebb/bebbhome.html
Flora of Texas Database	http://www.biosci.utexas.edu/prc/Tex.html
Kansas State University	http://www.k-state.edu/herbarium/research_policies.html
Black Hills Herbarium	http://herbarium.bhsu.edu/services.htm
Veg Bank-- ESA's Panel on Vegetation Classification	http://vegbank.org/vegbank/index.jsp

Table 3: Sources of osha location data, used for mapping and for Figure 1.

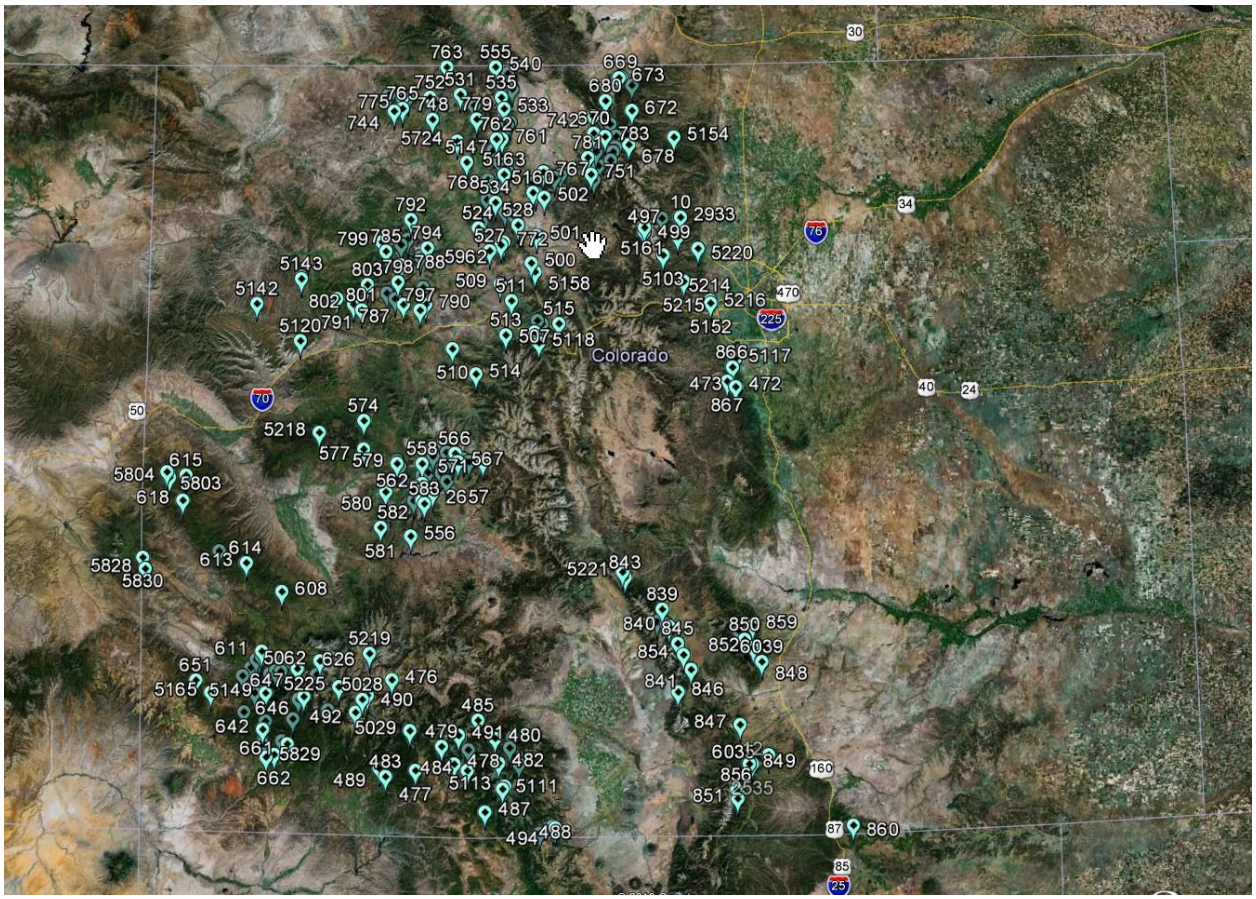

Figure 1: Locations of herbarium specimens for osha, *Ligusticum porteri* in Colorado. This map shows the distributions of osha are only in mountainous habitat. Our data were mapped using Google Earth.

Stands:

In mid-July 2012, we began our field research in the Cumbres Pass region of the Rio Grande National Forest in southern Colorado. In order to determine the population density of osha in the study area we mapped 8 polygons or stands (see Figure 2) that encompassed separate populations. Populations were separated by either large gaps (over 100 meters) with no osha occurrence or by the existence of a road. Thus populations were defined geographically rather than genetically. Each stand (a mapped polygon) consisted of a number of GPS marked waypoints approximately 100 meters apart on its boundaries. Approximately 20 meters toward the interior of the stand from each waypoint, the vegetative cover was determined in a randomly placed 4 m^2 plot, followed by two more plots each 5 additional meters to the right of the previous. Thus each waypoint corresponds to three 4 m^2 samples of the population. The amount of osha cover was approximated by the following categories: None (0%), Low (1-10 %), Moderate (10-40%), or Dense (40-100 %).

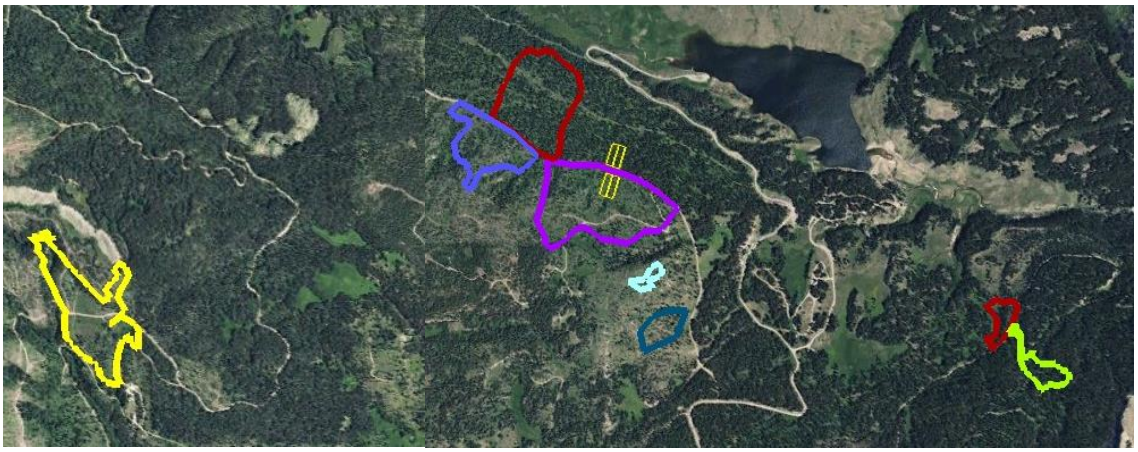

Figure 2: Outlines of eight polygons of osha populations for which osha cover data were collected. Note: Near the center of the map, the two yellow double-rectangles designate the area of our sustainability of harvest study.

Additionally, the U.S. Forest Service asked us to work with the local Hispanic community to improve awareness of osha harvest and conservation. Hispanic high school age youth from Costilla County's Sembrando Semillas program in San Luis, Colorado joined us in mapping the boundaries of our stands. They were very enthusiastic about the opportunity to contribute to our research, and for many of the volunteers this was their first exposure to scientific research.

Harvested Plots:

We analyzed osha populations on two sides of a road transecting a north-facing mountain slope. One site was on the uphill side of the road, and will be referred to as the Meadow site due to reduced canopy cover from logging and recent tree die off. The other site had the same aspect as the first, but was on the opposite downhill side of the road, and will be referred to as the Forested site due to significant mixed spruce-fir tree canopy cover (see Figure 3). The alignment of our sites assured that both slopes had the same sun angle orientation, allowing for a relatively controlled comparison of forested versus open locations. At each research site we established 2 parallel transects of 20 replicate 10x3 m plots, each spaced 2 m apart, for a total of 80 experimental plots. All plots ran perpendicular to the slope of the mountain. Transects A and B represent the 40 Meadow plots and Transects B and C represent the 40 Forested plots (Table 4).

Sustainability of Harvest Plots	**Min-Max Elevation (ft)**
Meadow A	10,409-10,500
Meadow B	10,399-10484
Forest C	10,209-10,369
Forest D	10,243-10,336

Table 4: Plot locations sampled for the Sustainability of Harvest study (mapped in Figure 2) and their elevations.

Figure 3: Photographs comparing Meadow and Forested plots.

Within each plot we recorded counts and cumulative percent cover for specific size classes of osha: seedlings, juveniles, mature non-reproductive, and mature reproductive, as well as the number of flowering stalks. To examine the effect of light availability on osha population density and post-harvest regeneration, we measured canopy openness within each plot using a spherical densiometer. Plots with fewer than 6 mature plants were considered null and omitted from the study because it would be difficult to discriminate differences in harvest intensity in such low density plots. Fourteen plots were considered null and therefore were not used in our experiment.

The harvest percentages of mature plants (defined as the largest size class) were in a regular repeating order of 0%, 33%, 66%, and 100% for plot numbers 1, 2, 3, and 4, and then repeating again, starting with plot 5. For a plot that had a 33% harvest, we dug every third mature plant, for 66% we dug two of every three plants, and for 100% every mature plant was dug. Plots with 0% harvest will serve as a control when we analyze the re-growth of harvested plots in subsequent years. In all, a total of 60 plots were subjected to harvesting activity (see Figure 4) while 20 plots were left unaltered. After harvesting we weighed and recorded the cumulative weight of the roots by plot. The boundaries of each transect and the corners of each plot were marked with GPS coordinates and buried steel rebar to ensure accurate location with a metal detector and reconstruction of plots in the following years of study.

Figure 4: Digging within Meadow plots, temporarily delineated with meter tapes.

Tagged Plants:

In addition to collecting harvest data on different treatments within the plots, we also recorded data on individual plants and marked their locations with a metal tag to be found in the next year of study. We recorded the X and Y coordinates of each tagged plant within its plot. At each site 125 harvested plants, distributed between the two transects, were replaced with a tag. This data on 250 individual osha plants will allow us to examine factors such as average root weights and the influence of habitat on root size, and will allow us to very precisely track potential re-growth related to root weight and size in the coming years.

Results:

Counts and Percent Cover in Plots:

A Meadow versus Forested plot comparison (see Figure 5) showed statistically significant differences in the number and percent cover of plants in the various age classes (Table 5). There were nearly twice the number of mature flowering individuals in the Meadow than in the Forested site, and consequently the Meadow exhibited a significantly higher number of flowering stems for seed production. In addition, we did not find one single seedling growing in the Forested site, while the Meadow site had many. The average percent tree canopy cover determined from a spherical densiometer was 17% in Meadow plots and 52% in Forested plots. This was also statistically different using the Mann-Whitney U test ($p<0.001$).

Count and Cover Summary	Combined Meadow	Combined Forest	All plots
Total # of Mature Flowering plants	**266.00**	**136.00**	402.00
Avg. Mature Flowering per plot	**6.82**	**3.49**	5.15
Avg. Mature Flowering % cover per plot	**0.05**	**0.03**	0.04
Avg. Flowering Stems per plot	**9.90**	**4.38**	7.14
Avg. Mature Non-flowering per plot	10.67	9.31	9.99
Avg. Mature Non-flowering % cover per plot	0.05	0.06	0.05
Avg. Mature plants per plot	**17.49**	**12.79**	15.14
Avg. Juvenile plants per plot	**5.87**	**3.38**	4.63
Avg. Juvenile % cover per plot	0.01	0.01	0.01
Avg. Seedlings per plot	**1.31**	**0.00**	0.65

Table 5: Counts and cumulative percent cover comparison between Meadow and Forested plots. Paired numbers highlighted in bold are statistically different using the Mann-Whitney U test ($p < 0.005$).

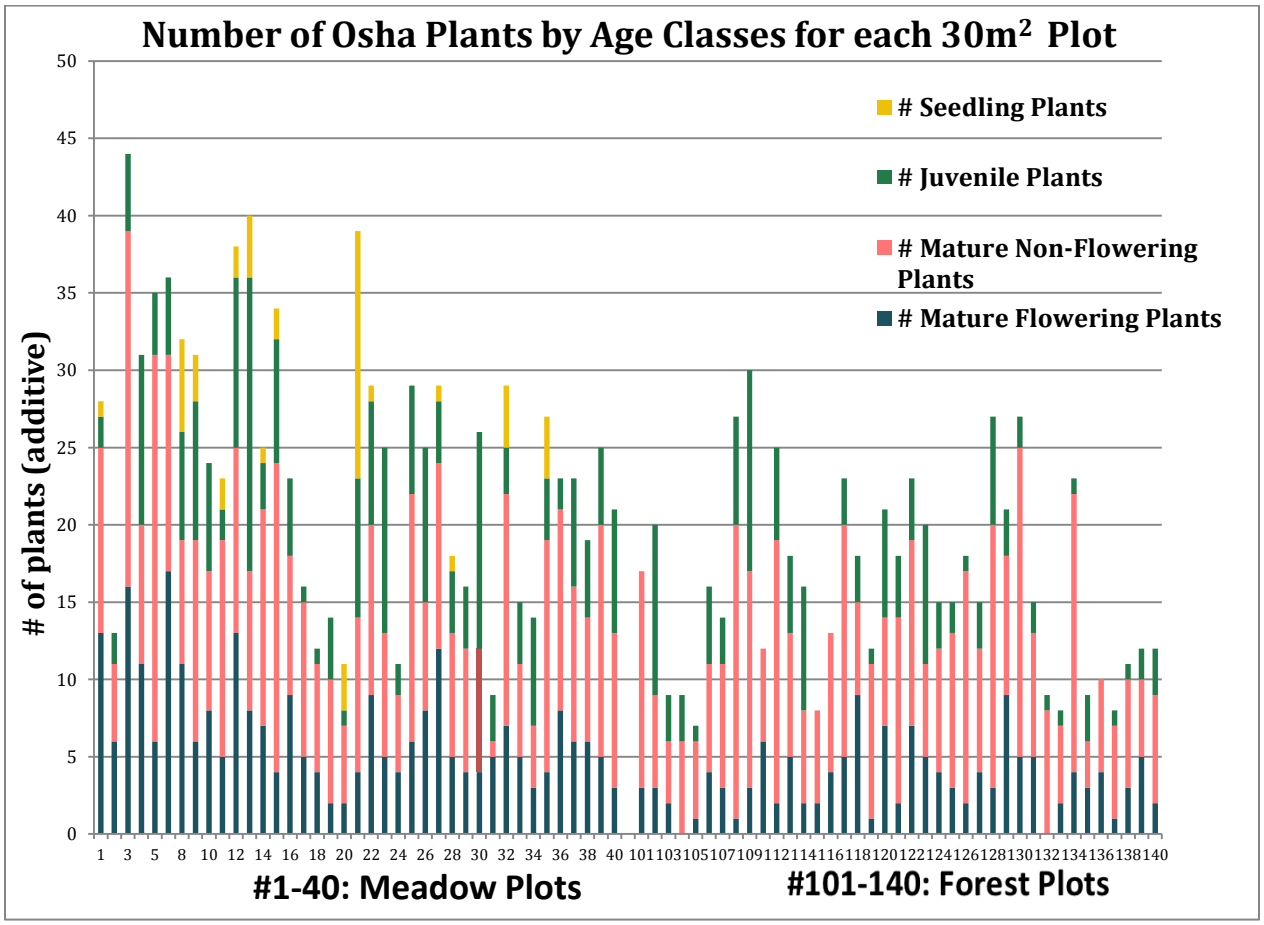

Figure 5: Number of osha plants for each of four age classes found within plots. Meadow plots exhibit more overall osha individuals. Of particular notice is the absence of seedlings in all Forested site plots.

Root Weights in Harvested Plots:

Not only did the Meadow versus Forested plot comparison show differences in the counts and cover of osha, we also found differences in the root weights in the two distinct habitats. In total, there were 1,181 mature plants (which includes both flowering and non-flowering mature plants) present from all plots in the two study sites combined. There were 15% more plants growing in the Meadow site than in the Forested site, and we were able to harvest 58% more total kilograms of root mass from the Meadow site than from the Forested site (Table 6). Additionally, the average weight of each individual root in the Meadow was more than double the weight of those found in the Forested (see root from a mature plant in Figure 6).

Weights Summary	Meadow	Forest	All plots
Totally # of plants dug	334.00	236.00	570.00
Total weight of roots dug (kg)	77.79	20.70	98.49
Total # of mature plants present	682.00	499.00	1181.00
Estimated weight of all roots present (kg)	122.59	32.30	154.89
Avg. weight of roots present in $30m^2$ area (kg)	4.23	1.11	2.67
Average weight of root per plant (kg)	0.29	0.11	0.20

Table 6: Summary of root weight comparison between Meadow and Forested plots.

Figure 6: An osha root harvested from the Meadow site.

For plots in which we only dug 33% or 66% of the plants present, we wanted to know how much root weight could be obtained had we dug every plant. We divided the measured weights of dug roots by the percent harvest in order to estimate total weight. This gives us an approximation of how much root weight is potentially present in an area. For sampled plots the average estimated weight of all the roots in a Meadow plot was quadruple that of all the roots present in a Forested plot (Figure 7).

Because osha is commercially sold as dried root, we took roots back to our lab and analyzed the ratio of wet weight to dry weight. We weighed 10 individual fresh roots of variable sizes and then allowed them to dry before weighing them again. On average, the dry weight of an osha root was 37% of its fresh weight. This is consistent with another study that found roots dried to approximately one-third their original weights (Guernsey 2005).

After calculating the potential fresh weight of all roots present in our 60 harvested plots, we converted this to a dried weight of around 57 kg (126 lbs). A thorough analysis of the online market found that whole osha roots sell for an average price of $55.54 per pound (Table 2). This means that the total value of plant material in our study plots would be approximated around $6,998—a substantial amount for a 2,400 m^2 area.

We used the data on root weights available in our harvested plots to calculate an approximate measure of the root weight that could be anticipated in a given stand of osha. We chose to convert our projection to dried weight because it is the commercially relevant value. The average percent cover of mature plants in the 30 m^2 Meadow plots was 10%, which correlates with .0522 kg dried root weight for a 1m^2 area (around 465 lbs/acre). The average percent cover of mature plants in our 30 m^2 Forested plots was 9%, which correlates with .0137 kg dried root weight for a 1m^2 area (around 122 lbs/acre). This information can be very useful for determining the economic potential of a given stand of osha that grows in environments with varying canopy cover. By sampling the percent cover of just a small portion of a population of interest, the potential weight of roots in that population can be estimated.

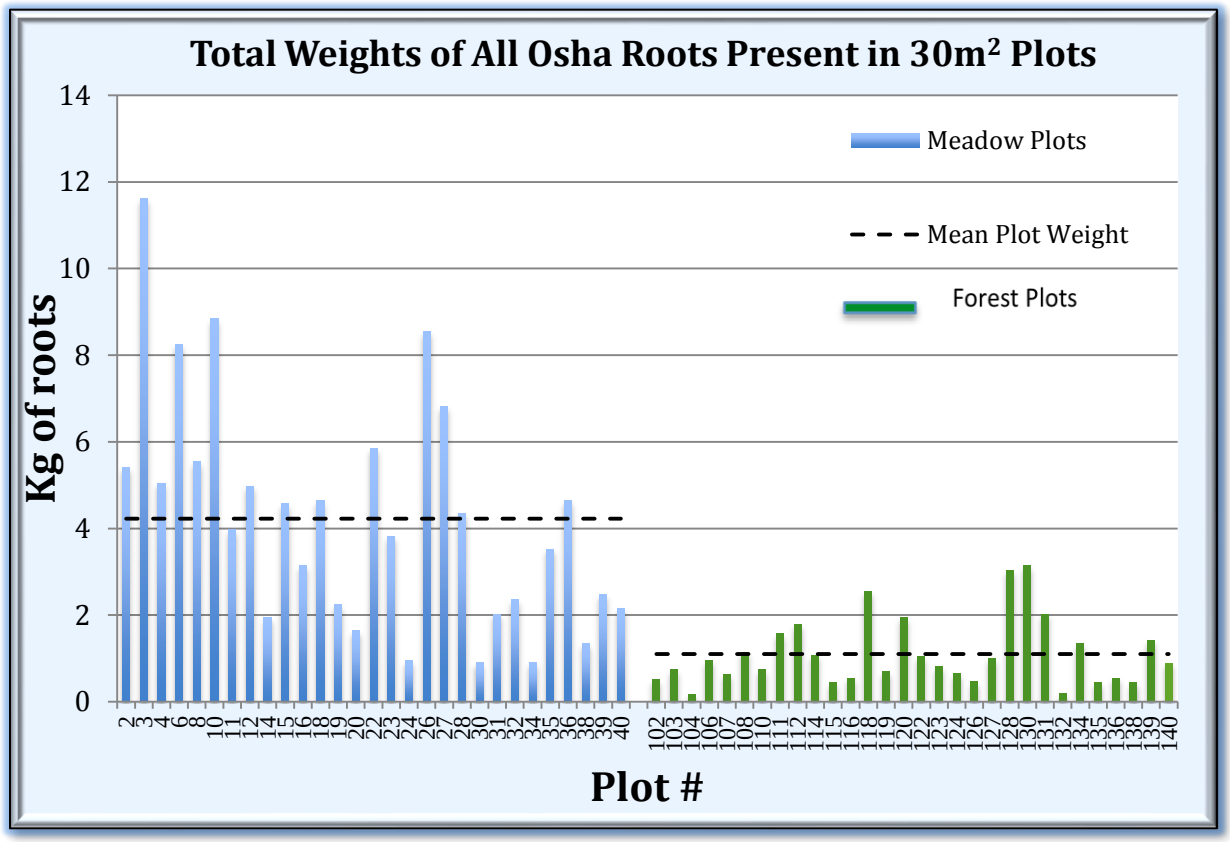

Figure 7: Total estimated root weight for all plants in each plot. The blue coloring indicates plots that were in a meadow environment, while the green coloring indicates plots that were in a forested environment. The black dotted lines represent the mean weight of roots present in a 30 m^2 plot for that site.

Stand	# of Waypoints	Area (m^2)	Perimeter(m)	Avg. % cover
1	13	6,221	445	12.29
2	8	22,316	617	2.38
3	82	101,108	2,373	9.80
4	40	156,391	1,732	12.11
5	56	122,225	1,426	7.31
6	20	14,273	672	4.58
7	27	18,670	972	5.28
8	36	66,394	1,358	8.75
Avg.				7.81

Table 7: Data for stands including their size and percent cover.

Discussion:

Our results illustrate osha's affinity for environments with more sunlight and less canopy cover. Although our study specifically analyzed osha populations in relation to sun exposure, the favoring of osha plants for the Meadow environment could stem from other factors related to tree cover including moisture levels, soil types, root horizon competition, and/or grazing intensity. Grazing levels especially have been shown to impact osha populations, with significant declines when over 50% of the population experiences grazing (Julander 1968). Although we did not include the effects of grazing specifically in our study because they were difficult to measure, it is of interest to note that the Meadow site was clearly impacted by the presence of cattle (dung piles and chomped stalks) more so than the Forested site, and still the Meadow populations had more plants and cover than the Forested populations. Our results suggest that overhead canopy cover has a strong influence on osha population density, however the specific underlying causes of these results remain unknown.

Although the Meadow population had more sun exposure relative to the Forested site, this does not mean that the population was in full-sun. Both elevation and slope significantly influence how a plant may respond to sun exposure. Our population was at a very high elevation, around 10,200-10,500ft (3109-3200 m), on a north-facing slope with an average grade of around 25%. Thus, the ability of osha to grow in areas of high sun-exposure (in our case as a result of past logging) is likely influenced by other factors that alter the microenvironment of a specific locality.

Of particular interest was the lack of any seedlings and a significant decrease in the number of flowering stalks in the Forested site. This illustrates a tendency for lower seed production among plants in a forested environment relative to an open canopy environment (Figure 8). This is a somewhat surprising finding given that it is typically assumed that osha seeds prefer moist soils, demonstrated by recent germination studies that use moist stratification followed by mist propagation (Panter 2004, Terrell and Fennell 2009). However, our findings indicate that osha has higher reproductive output and recruitment in open canopy environments, suggesting an optimal ecological role for osha as a canopy gap specialist.

Our specific data indicate a return of 465 lbs of dried root weight per acre of dense stands in open canopy sites. At an average wholesale price of $20/lb (a typical a harvestor might obtain), one acre of osha could be worth about $9,300, highlighting the strong financial incentive for wildcrafting osha. However, based on our preliminary data we cannot make any statement at this time regarding whether current harvest rates can be considered unsustainable or whether the population is being threatened by overharvest.

Figure 8: Osha produces a large number of seeds from its flowering umbels, especially in sunny locations.

Conclusions:

By analyzing the data from the Cumbres Pass area in the Rio Grande National Forest in southern Colorado, we found that changes in habitat light availability can have considerable effects on osha populations. From our data we conclude that a robust meadow population with low canopy cover that exhibits approximately 10% cover of osha will have on average 52.2 g dried root weight per 1 m^2 area (around 465 lbs/acre), while a forest population with a 9% cover will have on average 13.7 g dried root weight per 1 m^2 area (122 lbs/acre). In other words, open sites, such as meadows can have four times the amount of root weight when compared to forested sites. This information is important for the conservation status of this species; however, the subsequent years of our study will give us considerably more insight regarding the status of osha populations. Monitoring re-growth to estimate the resiliency or susceptibility of osha to harvest pressure will be critical for determining whether current wild-harvesting practices of this species are sustainable. Additionally, expanding our study over a broader area in variable locations and habitat types would provide a more accurate representation of osha's abundance at the landscape scale. After three to five years of study, we will be able to determine the impact of root harvest on osha populations, their reproduction and regeneration, and what the optimal rate of harvest should be to maintain the long-term viability of this important species.

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