2005 FINAL REPORT

Employing Natural Disturbance Regimes to Manage Rare Habitat Communities in the Willamette Valley

Metro Parks and Greenspaces
Curt Zonick – Project Manager

FWS Agreement # 1448-13420-02-J207
Report Date: August 17, 2005
Report Period: 7/1/04 – 7/30/05

Project Summary:

This grant project focuses on Metro's ongoing open spaces restoration program, targeting restoration projects that reintroduce natural disturbance regimes as a form of natural area restoration. Examples of such projects have included prescribed burning, seasonal flooding, managed grazing, etc. The project, as proposed addressed the important need for complimentary monitoring for such forms of management, as well as support for some aspects of restoration.

Work Tasks Completed:

1. **Botanical Monitoring at:**
    a. Cooper Mountain (Delphinium leucophaeum survey, upland prairie monitoring)
    b. Multnomah Channel (Floodplain shrub cover)
    c. Killin Wetlands (Floodplain herbaceous cover, Geyer willow surveys, floodplain shrub cover)
    d. Coffee Lake Bottoms (Floodplain herbaceous cover)
    e. Willamette Narrows (Delphinium leucophaeum survey)
2. **Native seed deployment at:**
    a. Cooper Mountain
    b. Killin Wetlands
    c. River Island
3. **Wildlife Monitoring (amphibian egg mass surveys) at:**
    a. Multnomah Channel
    b. Cooper Mountain
    c. Killin Wetlands
    d. River Island
    e. Gotter Prairie/Bottoms
    f. Coffee Lake Bottoms
4. **Wildlife Monitoring (avian breeding point count surveys) at:**
    a. Multnomah Channel

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b. Cooper Mountain
c. Killin Wetlands
d. River Island
e. Gotter Prairie/Bottoms
f. Clear Creek Ranch
g. Smith and Bybee Lakes

Project Staff and Partners:

1. **Metro Staff:**
   a. Curt Zonick, Senior Natural Resources Scientist
   b. Mary West, Volunteer Coordinator
2. **AmeriCorps/Northwest Service Academy**

Project Areas (Approximate areas associated with project)*

1. Cooper Mountain (10 acres)
2. Multnomah Channel (100 acres)
3. Killin Wetlands (60 acres)
4. Coffee Lake Bottoms (45 acres)
5. River Island (40 acres)

** See Appendix for maps and additional site information.*

Methods and Protocols (Appendix):

1. Egg Mass Surveys
2. Avian Breeding Bird surveys
3. Plant Monitoring

Ongoing Tasks:

1. All of the plant and wildlife monitoring is expected to continue beyond the project period. The wildlife monitoring is likely to continue on an annual basis. The plant monitoring will occur in some areas (e.g., Cooper Mountain, Multnomah Channel) on an annual basis, and at other sites on a biennial or every triennial cycle.

BUDGET

The budget, as proposed and current status, is presented below. (Current status is represented in parentheses-bound small bold text within selected budget categories).

Budget Items	Greenspaces funding request	Matching contribution		Total:
		In-kind value	pending/ received	
PERSONNEL **(existing staff eligible for matching contribution only)**	0	10,000 ($10,183.05 was provided in 2002/2003, $10,040.74 provided in 2003/2004, **$ provided in 2004/2005)**	0/10,000	10,000
VOLUNTEER LABOR **(valued @ $6.50/hour)**	0	2,000 (~400 hours, or $2,600 provided in 2003/2004, **$ provided in 2004/2005)**	2,000/0	2,000
PROFESSIONAL SERVICES **(include service sources, rates and hours)**	40,000 ($13,526.57 was used in 2002/2003, and ~20,119.89 was used in 2003/2004). **The final invoice of $6,353.54 for 2004/2005 completes the award.**	40,000 ($ 11,181.42 was provided in 2002/2003, $~ 15,000 accrued in 2003/2004, **$ provided in 2004/2005)**	20,000 /20,000	80,000
MATERIALS & SUPPLIES	0	5,000 ($ 139.38 has been provided, ~ 2,500 accrued in 2003/2004, **$ provided in 2004/2005)**	0/5,000	5,000
RENTAL FEES **(list equipment and rates)**	0	0	0	0
INDIRECT/ OVERHEAD COSTS **(eligible for matching contribution only)**	0	3,000 ($ 3,204.14 has been provided, **$ provided in 2004/2005)**	0/3,000	3,000
OTHER **(itemize)** Travel ($0.365/mi)	0	5,000	0/5,000	5,000
TOTALS:	40,000	65,000		105,000

Summary and Conclusions:

The project has proven extremely successful on many fronts. Priority ecological monitoring programs were established in part with USFWS grant funds at several key Metro natural areas. These programs and the data they have generated have shed light on important links between natural regimes and native and exotic species (e.g., stimulation of red-legged frog breeding population expansion via re-establishment of natural seasonal flood regimes at Multnomah Channel, apparent stimulation of Delphinium leucophaeum by prescribed burning at Cooper Mountain). Of course, many of these relationships will require many more years of monitoring and data gathering before these relationships can be defined with statistical confidence, but this grant and the projects it funded have successfully established the foundation for this important long-term work. Additionally, funds have supported the introduction of native vegetative establishment via native seed acquisition, as well as enhanced monitoring capabilities via the acquisition of GPS and field data entry equipment. These tools, and the monitoring arrays established through this program will serve Metro and the natural resource community well in the years to come.

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APPENDIX

Site 1. Multnomah Channel.

Located in Multnomah County along the west bank of the Multnomah Channel, this 325 acre tidally-influenced freshwater marsh supports substantial areas of native emergent wetlands (Figure set 1). The site supports at least four species of salmonids (Chinook, Coho, steelhead and coastal cutthroat) as well as such rare and sensitive species as northern red-legged frogs (although also eastern bullfrogs), purple martins, pileated woodpeckers and little willow flycatchers. Whereas large tracts of native vegetation persist, the site's wetlands are threatened by invasions of reed canarygrass, Canada thistle, Himalayan blackberry and other noxious weeds.

Management Unit

Metro partnered with Ducks Unlimited and the Natural Resource Conservation Service to install two water control structures at the site in 2001 to mimic flood cycles typical for the site prior to river-level management on the Columbia River. This approach will facilitate a "moist soils" restoration approach to over 150 acres of wetlands on site. However, due in part to grading done prior to Metro ownership, a large central tract of land now lies above the topographic limit of current flood management capability. Metro is pursuing a plan to contour portions of this central tract to bring about 15 acres of land currently lying above of the flood management zone affected by the water control structures (12-ft AMSL) into the flood management zone. The primary goal of this management is to restore a more natural hydrologic regime to the central tract to support the replacement by native emergent wetland communities of a dense growth of Canada thistle, reed canarygrass and other non-native species. This work is scheduled to occur during the summer of 2003.

Component of the project to be funded by Greenspaces Grant:

Metro is seeking support for the following components of this project:

- Planting and preliminary maintenance costs for
- Partial cost of 2002 and 2004 monitoring

Figure set 1. Maps and photos of Multnomah Channel showing location of site, location of described restoration, and current conditions. The site is located along Highway 30 in NW Multnomah County just east of the Wildwood Golf Course and across the Multnomah Channel from Sauvie Island (Upper left map). The Restoration area lies on either side of a causeway bisecting the property (see upper right aerial photo). Thistle and other non-native plants currently dominate the restoration tract (lower photo.

Site 2. Cooper Mountain

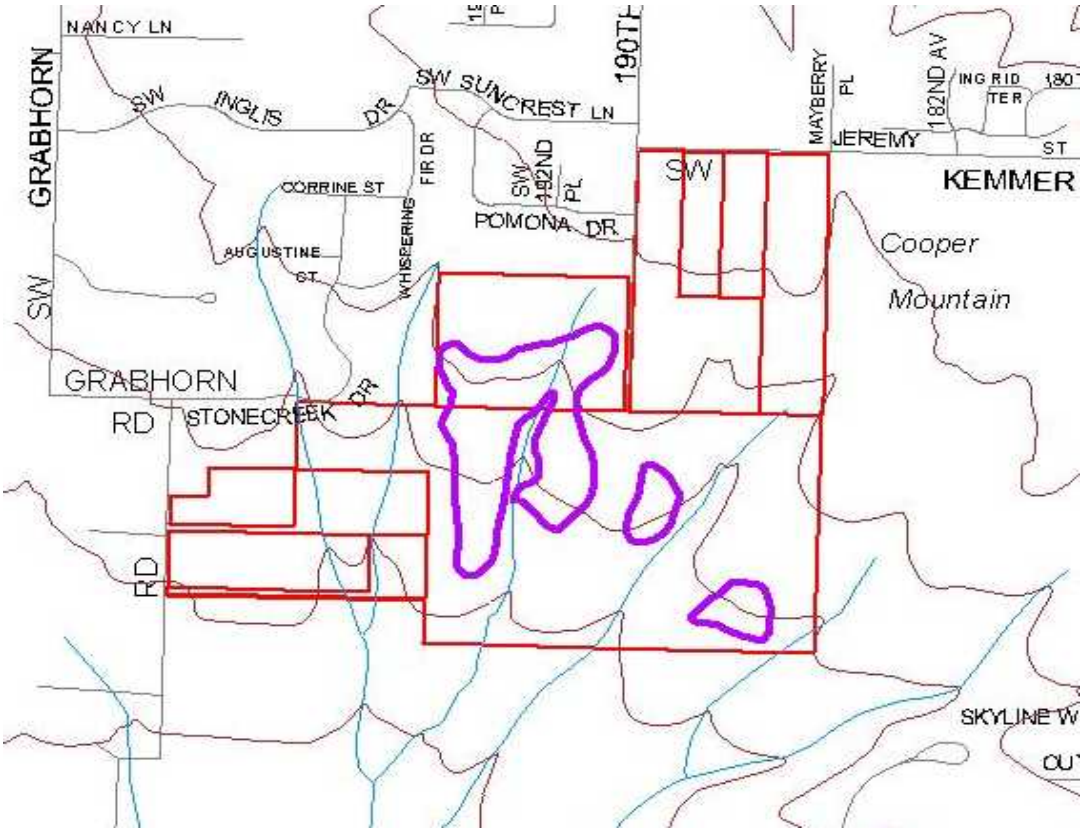
Located in Washington County west of Beaverton, this 250-acre site exhibits a mix of oak/madrone habitat embedded within a large tract of coniferous forest (Figure set 2). The site supports such rare species as northern red-legged frogs, western bluebirds, little willow flycatchers and an extremely diverse assemblage of native plants including one Oregon oak, madrone, Camas lily, and one of the most extensive population of the state endangered pale larkspur (*Delphinium leucophaeum*).

Management Unit

Metro has been conducting a controlled burn program on an 18-acre management unit in the heart of the site's oak woodlands since 1997. This burn unit also supports the large majority of the site's endangered larkspur population and numerous native wildflowers. In 2002, Metro will be replanting portions of the burned tract and plans to expand the areas of the site treated by prescribed burning.

Component of the project to be funded by Greenspaces Grant:

- Costs to replant burn units (Metro is considering adding several new units)
- Partial cost of 2002 and 2004 monitoring



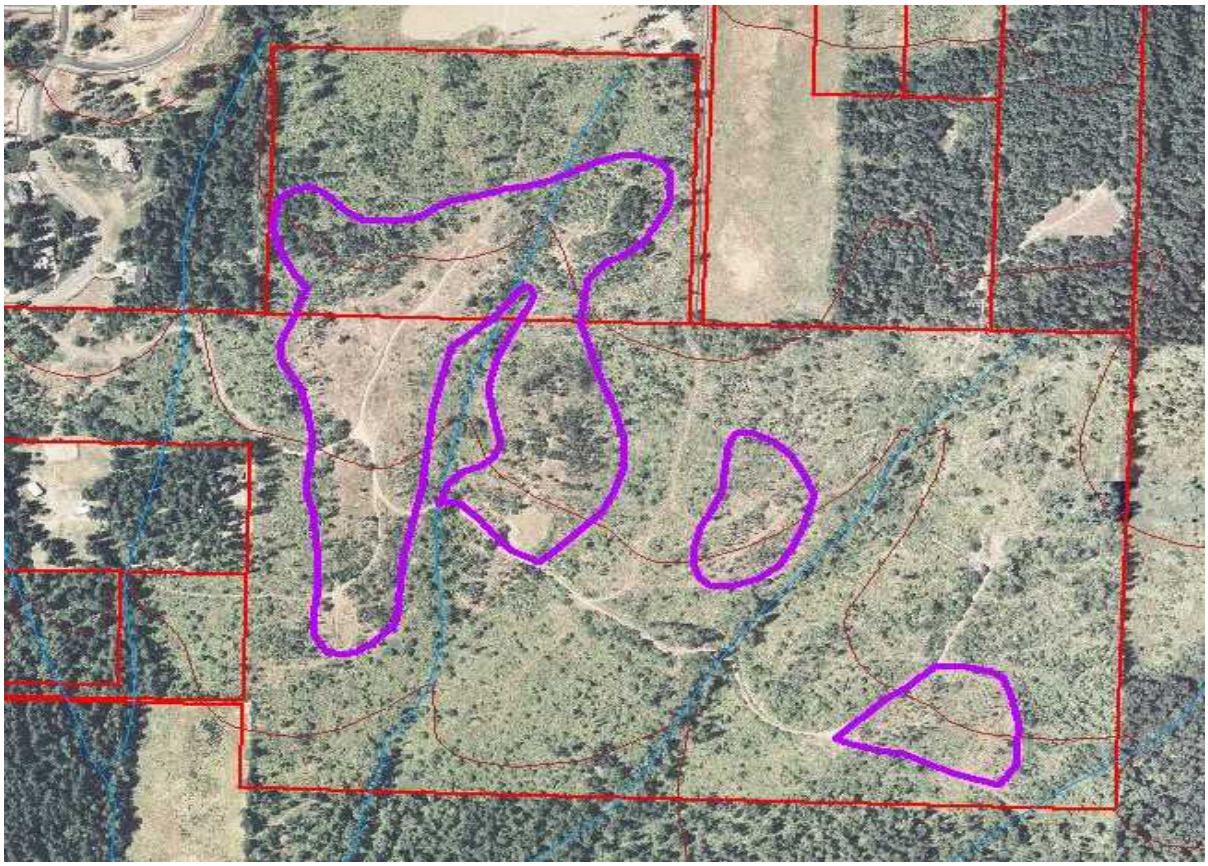


Figure set 2. Maps and photos of Cooper Mountain showing location of site, location of prescribed burn units, and photos of the 2001 burn and one of the many native wildflowers at Cooper (hound's tongue). The site is located on the southwestern slope of Cooper Mountain north of Scholl's Ferry Road (see map on previous page) and is characterized by its diverse oak savannas. Three active burn units are situated within south facing rocky slopes on the property (see top aerial photo, this page; burn unit boundaries shown as bold purple lines).

Site 3. River Island

Located in Clackamas County along the banks of the Clackamas River, this 240-acre property includes a 25-acre field with a small fragment of Oregon oak savanna (Figure set 3). The field is a former pasture that is currently dominated by noxious weeds. The site lies across the Clackamas River from a regionally rare breeding colony of bank swallows, and adjacent to two large ponds that support northwestern painted turtles.

Management Unit

Metro is planning to establish a prescribed burn program within this field in 2002 and to replant the remainder of the field as an Oregon oak/ponderosa pine savanna within a native short and associates (i.e., Oregon grape, *Ceanothus*). Plantings will occur within large islands that can be surrounded with fire lines to allow a controlled burn program to commence immediately (i.e., before the trees have matured to a stage at which they can survive fire management.) The open, savanna habitat will be ideal for nesting turtles, foraging swallows (including violet green and tree swallows) and other native wildlife species.

Component of the project to be funded by Greenspaces Grant:

- Costs to re-seed, replant and maintain field
- Partial cost of 2002 and 2004 monitoring

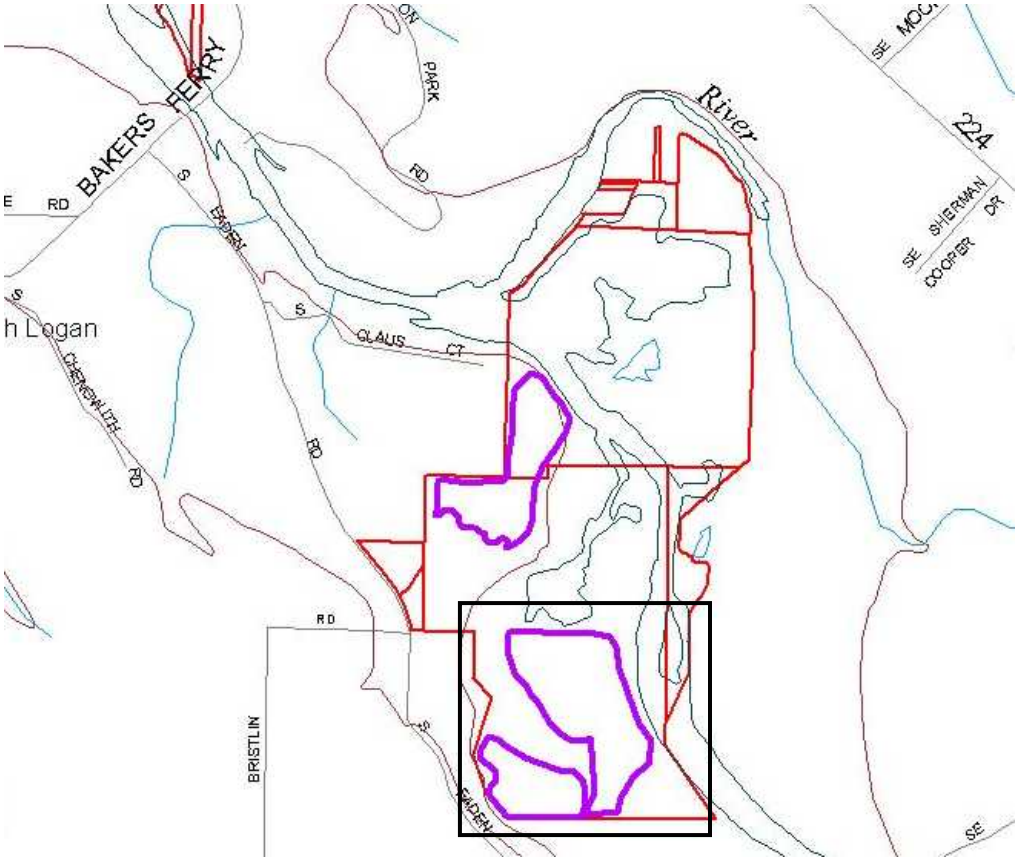


Figure set 3. Maps and photos of River Island showing location of site, location of prescribed burn/savanna units, and a photo of one of the site's ponds with an artificial turtle basking structure. The site is located on the banks of the Clackamas River southeast of Barton Park (See map of site on previous page). Putative burn units are delineated in thick purple outlines (See map on previous page and aerial photo, this page, upper left). The tract planned for restoration under this grant lies within the larger comma-shaped tract in the southeast corner of the property (See panoramic photo, this page, lower). A few large oak trees (See photo, this page, upper right) can be seen in the northern part of this tract on the aerial photograph.

Site 4. Coffee Lake Bottoms

Located primarily in Clackamas County, northwest of Wilsonville, this 130 acre floodplain site was shaped by the Bretz floods which established a number of unique geologic formations in the region, including "kolk" ponds (of which Coffee Lake is one), channels, basalt hummocks and knolls. The area supports such rare species as northern red-legged frogs, little willow flycatchers, and northwestern pond turtles. Unfortunately, the wetland community is dominated by reed canarygrass and other noxious weeds.

Management Unit

Metro is partnering with Ducks Unlimited and the NRCS to establish a dynamic seasonal flood regime to counter the effects of the Seely Ditch and other regional factors that have reduced flooding amplitude and periodicity at the site.

Component of the project to be funded by Greenspaces Grant:

- Costs to replant portions of new flood units
- Partial cost of 2002 and 2004 monitoring

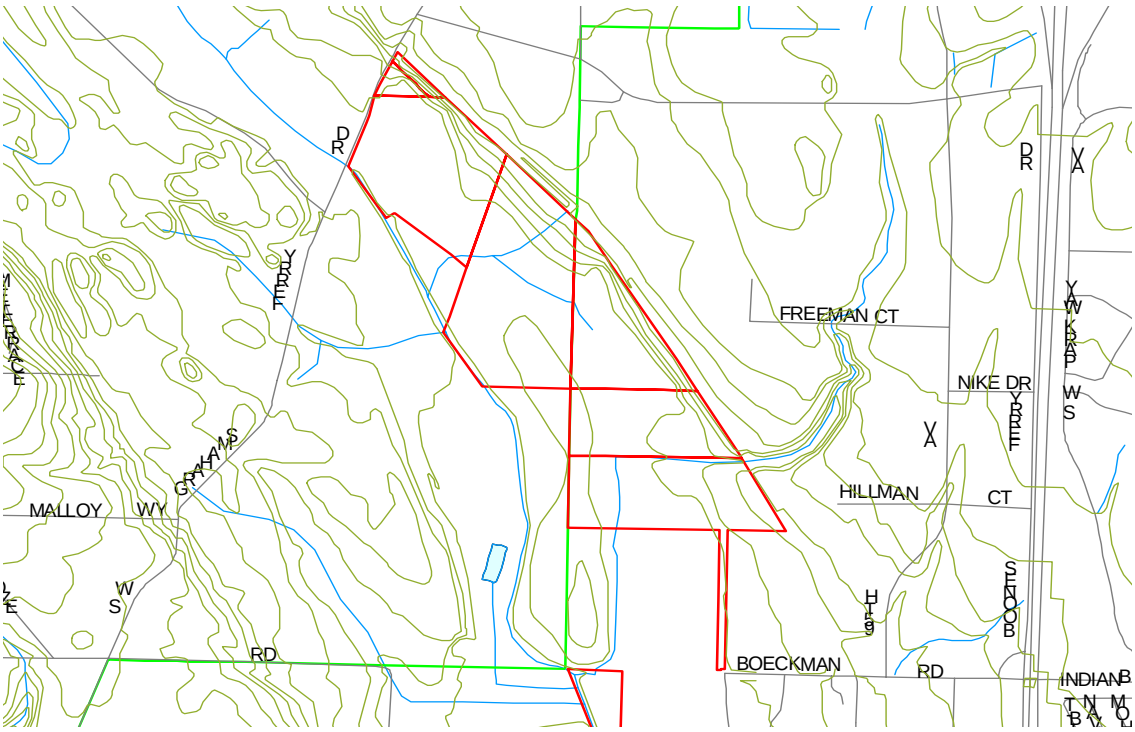


Figure set 4. Map and aerial photo of the Coffee Lake. The site is located just northwest of Wilsonville within a floodplain scoured by the Bretz floods (See map, pervious page). A panoramic photo of the north wetland unit is shown on the previous page (lower). The aerial image on this page (upper left) shows Metro property boundaries (*note: Metro recently acquired another large tract near the bottom of the photo*). Coffee Lake is seen as a dark patch near the center of the aerial photo (the lower photo was taken along the southern portion of Coffee Lake, looking North). The site supports red-legged frogs (egg mass photo, upper right).

2001 Aerial image of the Oak savanna site overlaid with property boundaries (red line), 1996 flood limits (blue line) and oak units (orange lines). As this map illustrates, the oak units are located above the 100-yr-flood zone.

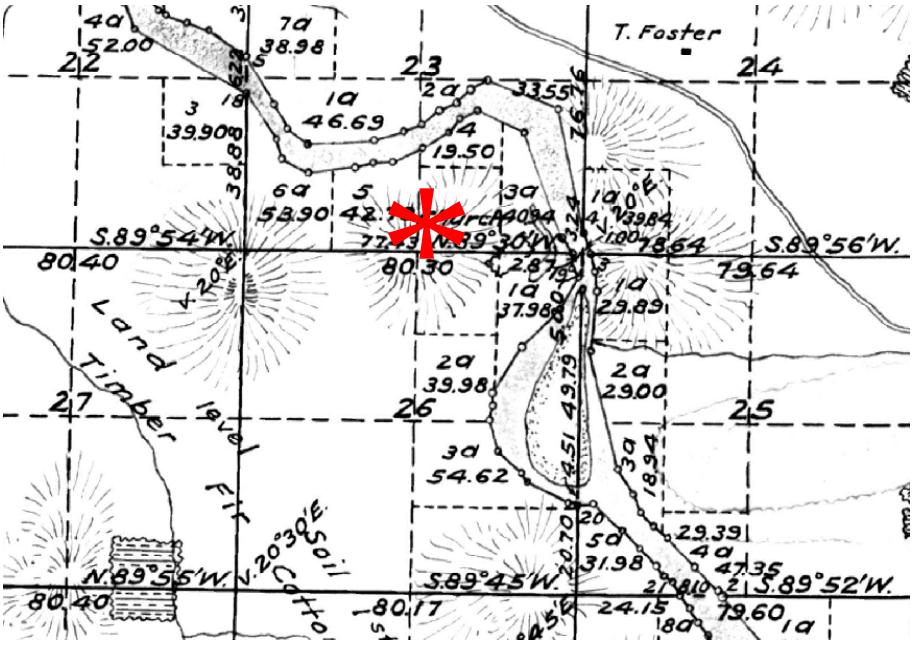
Another question related to the historical presence of oaks and open woodlands in the region and tract. We have begun investigating this. Unfortunately, the historic vegetation summaries compiled for much of the Willamette Valley do not extend far enough into the Clackamas to cover the fields in question.

So, we visited BLM and copied the microfiche from the 1800's government land surveys and have ***begun*** *evaluating them (See map below). The* ***notes*** *are cryptic and faint, and we've not yet printed them out but have just cursorily reviewed them on a very old microfiche projector – but, they do describe on several accounts oaks and in at least one passage open woodlands for the two section flanking the fields.*

For example, one quote from Section 35, just south of the field:
"Land open, soil 1st rate, timber scattering fir and oak".

Obviously, we will press on with the research, but feel a little better about pursuing Oak woodland management in this area.

Again, our motives are also augmented by the presence of bank swallows, painted turtles and other species that would benefit from more a more open local landscape for nesting and foraging habitats.



Map from government land surveys conducted in the late 1800's. The red asterisk identifies the approximate location of the field to be planted in Oregon oak and associates.

Hyperspectral Imagery component of "Employing Natural Disturbance Regimes"

I. Name of the Cooperator: Metro Regional Parks and Greenspaces

Cooperative Agreement Number: 1448-13420-02-J207

Date of Report: August 16, 2005

Project time period: June 2003- August, 2005

II. Project descriptions, including a comparison of expected and actual goals, accomplishments and benefits:

Metro evaluated a process using imaging spectrometers to determine if spectral signatures from individual invasive plant species could be identified and differentiated. The importance of being able to differentiate these signatures could result in mapping of areas with invasive infestation in order to prioritize activities for restoration. The first step involved testing a portable hand-held spectroradiometer to gather reflectance spectra of target invasive species. The second step involved reading these spectral signatures from two invasive species, Himalayan Blackberry and Scotch broom. Results showed that the hand held spectroradiometer could read the spectral signatures in both the visible and the infrared spectrum for both the invasive species. These signatures were species specific and could be differentiated in both the visible and invisible spectrum.

Identifying and differentiating spectral signatures may have important applications for restoration activities. One application of this method involves attaching an imaging spectrometer to an aerial flight of our properties. These air borne spectral signatures could then be analyzed to recognize different invasive plant species and their communities. This type of data gathering operation would be helpful in monitoring restoration projects and identifying the spread of invasive species, further reducing the time spent on the field monitoring invasive species, decreasing costs in the long term and increasing efficiency on the field.

We had originally planned to develop a library of spectral signatures for a suite of 20-30 plant species, however we only acquired spectral signature of two species; Himalayan blackberry and Scotch broom. The instrument broke and the main researcher on this project left for employment. Both these activities resulted in Metro changing the scope of the work and diverting the excess dollars to another grant funded project.

III. Actual work tasks implemented and the associated schedule:

The hardware and software tested worked adequately to collect quality plant reflectance at 350-1050 nm with 1nm resolution to analyze spectral reflectance characteristics. Very high quality data was collected on two species, Himalayan Blackberry and Scotch broom.

The data collected demonstrated spectral difference between these tested species over various parts of the visible and infrared spectrum.

IV. List of project staff and partners, and their roles. Include the number of volunteers and other participants involved, along with the associated number of hours contributed to the projects.

MATCH

1. Michael Pence (MP), consultant, Ordered the instrument, did the field work and analyzed the data and coauthored the report with Jennifer and Ralph.
   Match 100 hours at $35/hour - $3,500 (work done prior to project starting). See hours below-
2. Jennifer Budhabhatti, Project manager – analyzed the data and co-wrote the report with Michael. Match 45 hours $1,432.18
3. Ralph Garono (RG), consultant, Consulted to review the methods and the results.
4. Curt Zonick, Metro staff, reviewed the methods.

ACTUAL COST

TASK	TIMELINE	LABOR HRS	Dollars spent
1. Research and rent a hand held spectrophotometer (MP)	June 04	20 hrs x $35	700
2. Field test equipment and train with firm that provides the spectrophotometer(MP)	June 04	20 hrs x $35	700
3. Field test equipment on selected sites and gather at least 20-25 signatures(MP)	July- Aug 04	40 hrs x $35	1,400
4. Use a software to download the image and analyze it (MP)	September 04	27 hrs x $35	$455
5. Ralph's consulting fee(RG)	September 04	4 x $80	320
6. Short report illustrating images and short write up on all methods used, findings and management implications(MP)	October- Nov 04	19.9hrs x $35	799.80
Other costs mileage etc…		$100	46.15
Cost of renting		$1,200	349.79

equipment			
TOTAL			$4,770.74

V. Project Area: Not applicable

VI. A description of the methods used to implement the projects and the effectiveness of those methods.

A commercial spectroradiometer system (Analytical Spectral Devices Fieldspec Pro VNIR) for data collection and analyses was used to measure spectral data from two invasive species Himalayan Blackberry and Scotch broom. Several test analyses was done on the field at the Multnomah Channel site to determine the best position to record the data. Test data was collected from the Cooper Mountain Metro Study.

Data was collected during the month of July between 10 and 2:00 pm to allow for the best possible illumination and to eliminate shadows. Repetitive signature datasets were collected for each species using a height of 1 inch (0.025 meter) and 6 inch (0.15 meter) from the top of the plant. Spectral reflectance data was also collected from plant structures such as leaves and flowers.

VII. Ongoing tasks that will continue beyond the term of this Cooperative Agreement, such as monitoring and maintenance or next steps.

Presently, no next steps have been discussed.

VIII. Summary of expenditures and project costs see no 3

IX. Summary and conclusions. Include observations and advice from this project experience that may assist others involved in similar work.

Though this project was successful on a smaller scale, additional steps are recommended for future monitoring projects:

1. Increase the sample size of invasive species to be monitored such that a library of spectral signatures could be recorded.
2. Test different heights at which the recording is taken to identify the ideal height from which to position the spectroradiometer and get optimum readings. This standard height could then be used to gather all the data.
3. Capture spectral signatures during different times during the summer to choose the best week and time to take readings in order to best differentiate between the species.

X. Copies of data
See attached report

Evaluation of Spectral Imagery as a Tool to Differentiate Among Plant Species

Michael Pence - OrganiSyn Consulting, Lake Oswego, OR 97035,
Jennifer Budhabhatti - Metro Parks and Greenspaces, Portland, OR 97232,
Ralph Garono - Earth Design Consultants, Inc., Corvallis, OR 973331

[Note: This study was funded, in part, by a Greenspaces grant sponsored by the U.S. Fish and Wildlife Service and Metro.]

SUMMARY

Metro used imaging spectrometers to determine if spectral signatures from individual invasive plant species could be identified. The importance of being able to recognize and differentiate these signatures could result in mapping of areas with invasive infestations. The first step involved testing a commercial hand-held spectroradiometer to gather reflectance spectra of target species. Metro prepared a list of target species to be analyzed through spectral signatures. In addition, test runs were done on analyzing spectral signatures from plant components such as leaves, berries and stems.

During the summer of 2004, spectral reflectance data (350-1000 nm) were collected on Himalayan Blackberry (*Rubus discolor*), Scotch Broom (*Cytisus scoparius*) and several other sample test species by using a commercial spectroradiometer -Analytical Spectral Devices Fieldspec Pro VNIR. Field operations and data collection methods were first defined in the field, and then data collected on the target species. The data collected demonstrates differences between tested species over various parts of the visible and infrared spectrum, even within the short test period**.**

For example, Himalayan Blackberry (HB) leaf exhibited a ~25% reflectance peak in the visible spectrum of 550 nm and 90-100% reflectance in the infrared spectrum of 720-1000 nm. The berries and stem also exhibit unique signatures. Immature berries (red) have a visible reflectance peak of 25% near 640 nm and a reflectance of 85-90% in the infrared spectrum of 800-900 nm. Mature blackberries have almost no reflectance in the visible and minimal in the infrared (5-10%). HB stem has very little reflectance < 5% in the visible with a peak near 640 nm and a reflectance of ~65% in the infrared spectrum of 740-920 nm. Scotch Broom (SB) has less dramatic spectral features (in summer). Overall, reflectance was less than HB (<10% reflectance in visible, peak near 550 nm, ~20% reflectance in infrared broadband), probably due to SB's dark green stem and overall architecture. The data collected is the first step in building a local spectral signature library.

Introduction

Metro Regional Parks and Greenspaces owns and manages approximately 11,000 acres of property in the Portland area. Most of Metro's properties are invaded by invasive species. Controlling invasive species is costly and time consuming. The suppression of invasive plant species and introduction or expansions of native communities are central goals to most restoration projects on these lands. Monitoring population trends in these communities, and specifically, suites of individual species, is therefore a high priority. Metro initiated an imaging spectroradiometry study to collect widespread, accurate, and precise measurements of a series of plant targets in a platform that will support long-term monitoring.

In the past, Metro has used remote sensing, aerial photo mapping and ground surveys to gather vegetation data. Metro's remote sensing analyses extracted spectral information at a coarse scale without being able to distinguish plants at a species level. Information from aerial photos is limited in its ability to distinguish species level data without a field visit. As a result, the only way to recognize species level information is by obtaining on-the-ground information. Fieldwork is expensive and time consuming and needs to be repeated over time with great precision to yield useful data and reliable trend analyses. For these and other reasons, spectral analyses offers a standardized alternative allowing more cost effective and precise species-level monitoring over a broader region.

Living plants absorb and reflect light at specific wavelengths that can be analyzed to discern the species of the plant and its health. Thus each plant and its associated structures emit a particular spectrum, depending on the structural integrity of the plant. Metro investigated the capabilities of using imaging spectrometers to measure these spectra. These "spectral signatures" were analyzed to determine if invasive plant species could be identified and distinguished from each other and their surrounding vegetation. We expect to use this information in the future to develop cost effective greenspace management assessment methods for control of invasive species.

One application of this method involves attaching an imaging spectrometer to an aerial flight that would fly to the boundaries of our properties gathering spectral signatures. These spectral signatures could then be analyzed to differentiate invasive plant species and their communities. This type of data gathering operation would be helpful in monitoring restoration projects and identifying the spread of invasive species, further reducing the time spent in the field monitoring invasive species, decreasing costs in the long term and increasing efficiency in the field.

Goals and Objectives of the Project

To determine if spectral signatures could be differentiated among invasive species by using an imaging spectrometer**.**

Objective # 1 - Obtain and use a commercial hand held spectroradiometry in a field setting.

Objective # 2 - Evaluate the software and hardware of the hand held spectroradiometry to determine if the band settings in the visible and infrared setting were able to differentiate between selected invasive plant species.

Methods

A commercial spectroradiometer system -Analytical Spectral Devices Fieldspec Pro VNIR (ASD) was selected for data collection and analysis (Image 1). Several days were spent learning the hardware and software functions and preparing for mobile field operations. Data collection methods were then defined and tested in the field at Multnomah Channel, and test data collected on two invasive target species (Himalayan Blackberry (*Rubus discolor*) and Scotch Broom (*Cytisus scoparius*) at the Cooper Mountain Natural Area.

Reflectance or spectral data was collected at both the visible and at the infrared spectrum ranging from 350 to 1050 nm (Figure 1). Test data were collected under optimal environmental conditions on July 15 between 10 am and 2 pm to allow for the best possible illumination conditions and to eliminate shadows. Repetitive signature data sets were collected by placing the hand-held ASD at 0.025 meter (1 inch) and 0.15 meter (6 inch) from the top of the plant. Spectral reflectance data were collected on specific plant structures by placing the ASD at a distance of 0.025 meter to spectrally dissect plant composition and then at a distance of 0.15 meter to compare species signatures.

Image 1 – Portable Analytical Spectral Devices (ASD) Spectroradiometer with fiber optic cable, pistol grip, and remote cosine receptor. The spectroradiometer is equipped with a battery pack and shoulder straps for field operations.

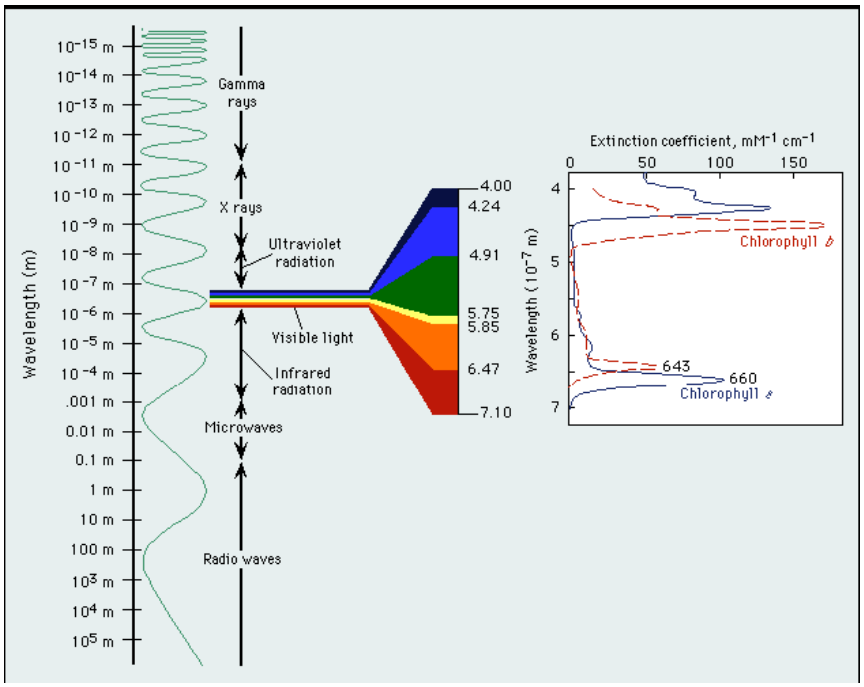
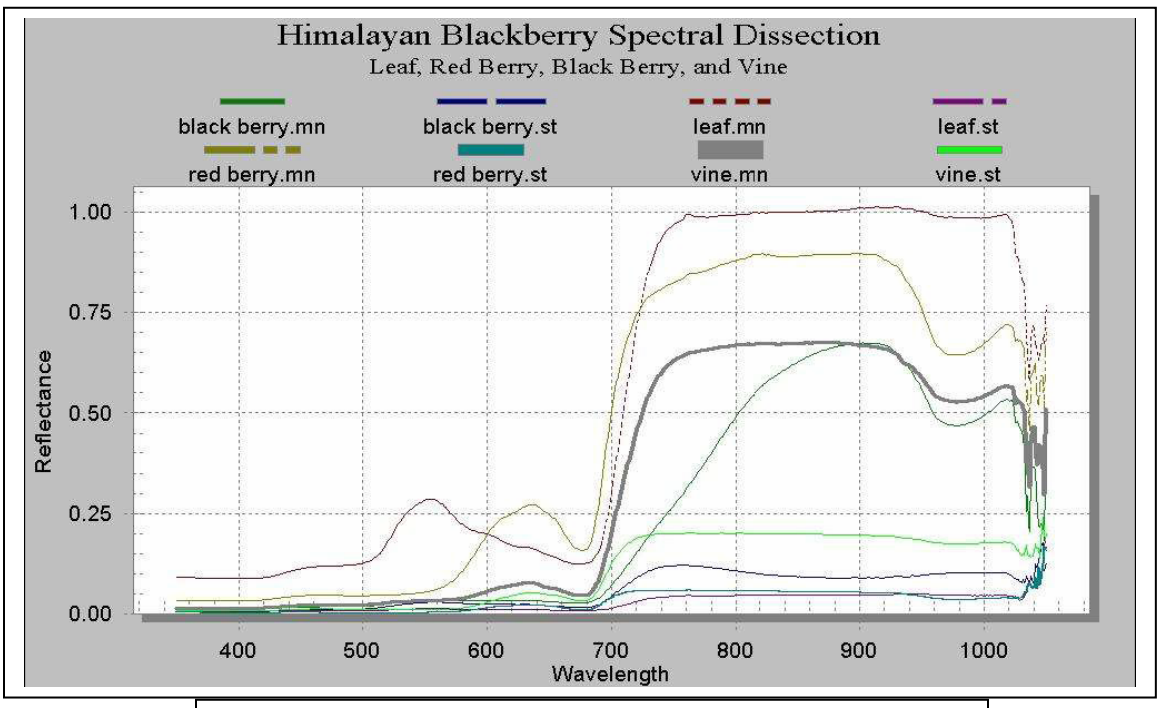
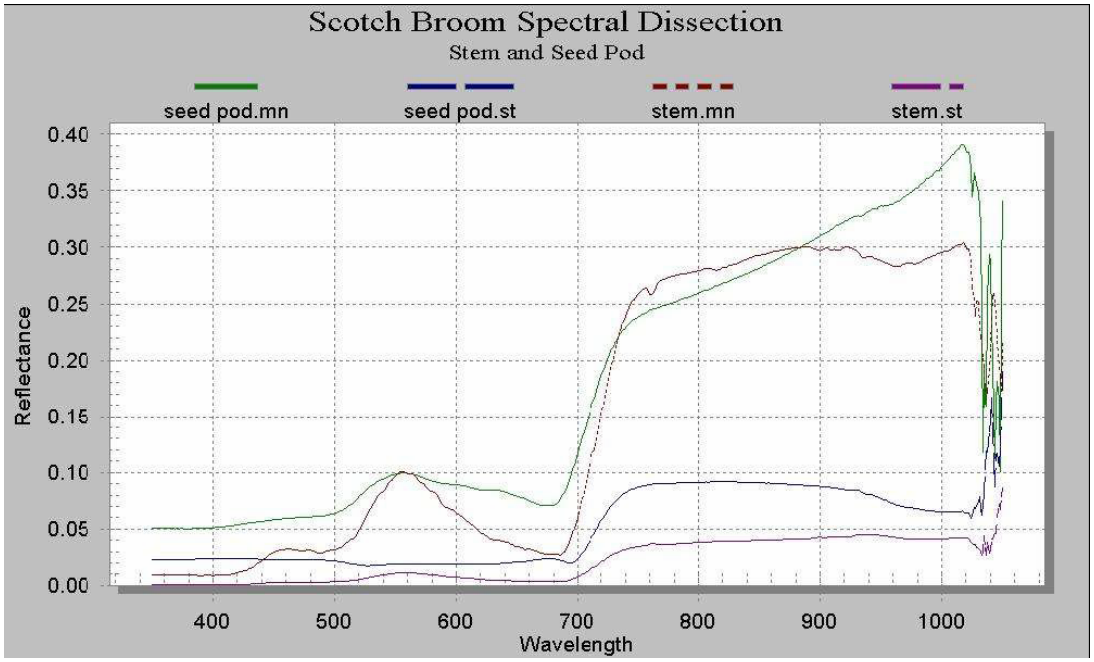


Figure 1- A diagram of the electromagnetic spectrum.



Graph 1- Himalayan Blackberry Spectral Reflectance at 0.025 diameter footprint. Reflectance is measured as watts/square meter/nanometer.

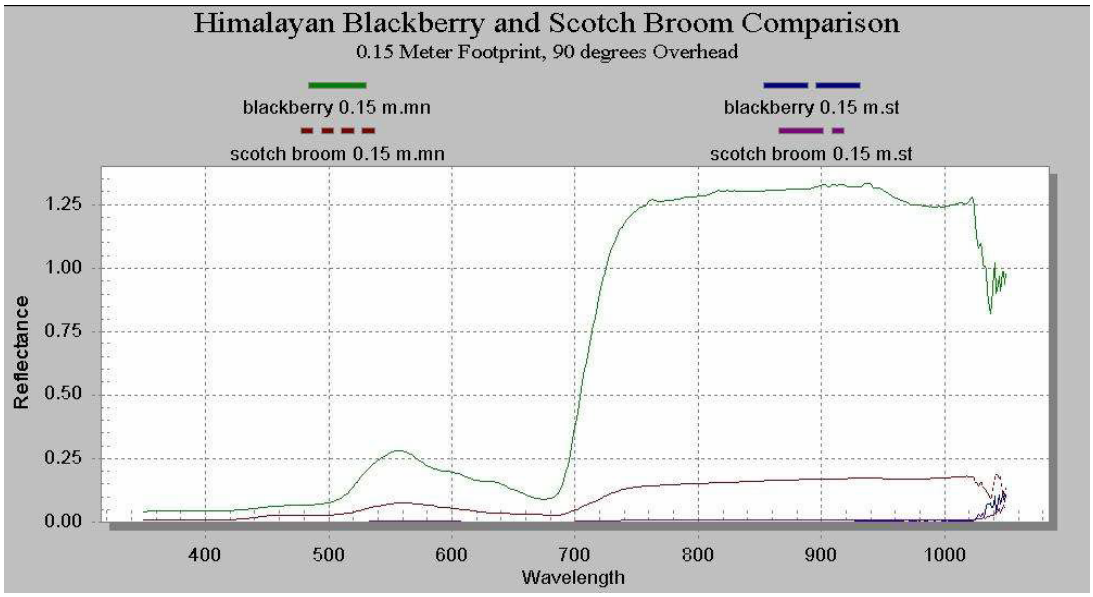
Image 2 and 3 - Berry bracts constitute a large portion (~30-50%) of the Himalayan Blackberry architecture in the summer season.



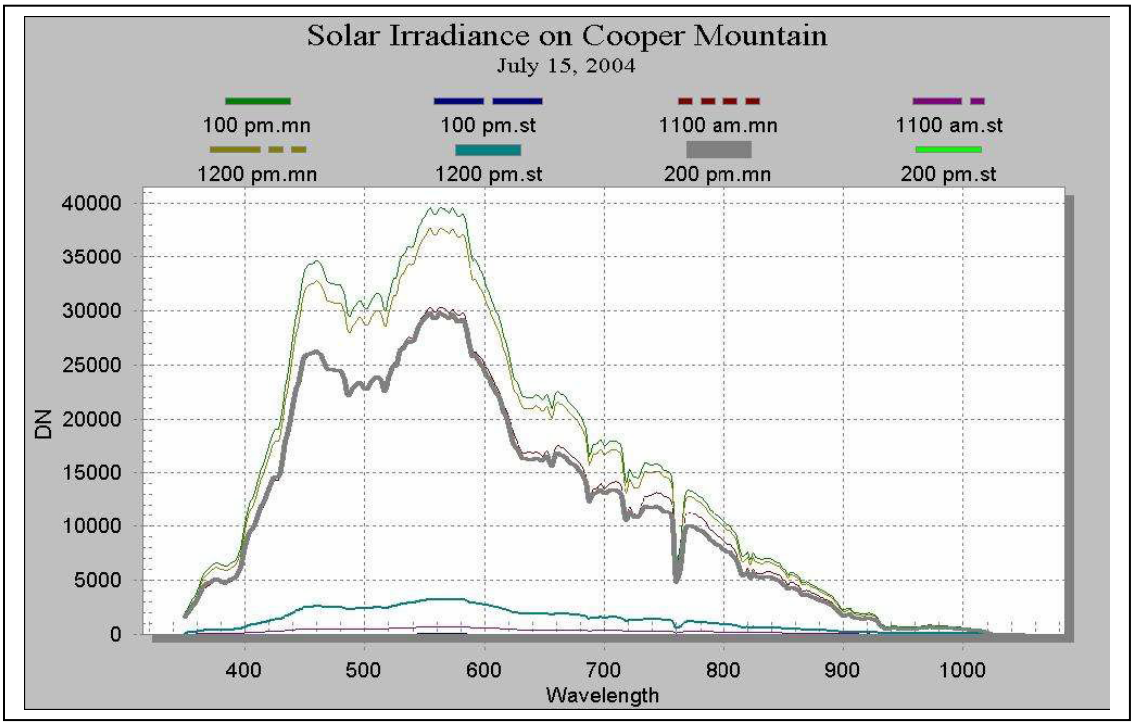
Graph 2- Scotch Broom Spectral Reflectance at 0.025 diameter footprint. Please carefully note when comparing graphs 1 and 2, that reflectance axes are not equal.

Image 4 - Close-up view of SB architecture.

Image 5- Overhead view of SB. SB architecture is very sparse and ~50% "open" allowing light to pass through unreflected, which results in a lower spectral reflectance.



Graph 3- Comparison of Himalayan Blackberry and Scotch Broom Spectral Signatures.



Graph 4 – Remote Cosign Receptor (RCR) data of solar illumination during data collection.

Results

The hardware and software tested worked adequately to collect quality plant reflectance data at 350-1050 nm with 1 nm resolution to analyze spectral reflectance characteristics. Spectral reflectance data was successfully collected on Himalayan Blackberry (HB)(Graph 1) and Scotch Broom (SB) (Graph 2). The data demonstrated that spectral differences exist between these tested species over various parts of the visible and infrared spectrum (Graph 3).

HB leaf exhibits ~25% reflectance peak in the visible spectrum near 550 nm and 90-100% reflectance in the infrared region of 720-1000 nm. The berries and stem also exhibit unique signatures. Immature berries (red) have a visible reflectance peak of 25% near 640 nm and 85-90% reflectance in the infrared region between 800 and 900 nm. Mature blackberries have almost no reflectance in the visible and minimal (5-10%) in the infrared. HB stem has very little reflectance (< 5%) in the visible with a peak near 640 nm and ~65% reflectance in the infrared region between 740 and 920 nm.

SB has less dramatic spectral features in summer. Overall, reflectance was less than HB, <10% reflectance in visible, peak near 550 nm, ~20% reflectance in infrared broadband,

probably due to SB's dark green stem and overall architecture. SB seedpods had a wide peak near 550 nm in the visible, and a 10% continually increasing reflectance in the infrared region of 740 and 1000nm.

Discussion

The project goal was met. The use of the ASD hardware and software was fairly easy to learn and user friendly, and adequately gathered spectral reflectance data for analysis. Species differentiation was successful with the pilot study that was completed. The difference between the signatures could be explained by different structural differences between the two plants. The Himalayan Blackberry structure is composed of leaves and berries, during the summer, which lead to high peaks in the visible and infrared spectrum. Whereas, Scotch Broom has a dark green lowly reflective stalk, no flowers, and has lost its small leaves (Images 2, 3 and 4) resulting in low reflectance. Further data collection, however, is recommended to fully characterize signatures from other invasive plants.

Conclusion

●The equipment and software tested worked adequately to gather spectral reflectance signature.

● The study was able to demonstrate that specific spectral features from plants can be discriminated, specifically in Himalayan Blackberry and Scotch Broom.

Future Efforts

Presently, no further activities have been planned related to this project. In the future, it would be important to develop a library of signatures for different invasive and native species. This could be followed up by a test flight to identify spectral signatures and determine if the library would assist in differentiating the spectral signatures from different species

NOTES

More data collection was planned on other invasive species, but the pilot study was cut short due to a malfunction of the instrument caused by an accident. This malfunction and the resignation of the principal investigator resulted in the project ending and the remaining funds being used on another project.