Chapter 9

Ecological Studies at the Lehigh Gap Wildlife Refuge

LGWR Ecological Studies

Total Cover Analysis

A significant portion of the LGWR is a part of the Palmerton Superfund site, and thus, any restoration work and monitoring done at the site must comply with the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA; commonly referred to as the Superfund Legislation). One of the three goals of the EPA's Record of Decision for the Palmerton Superfund site is to revegetate denuded areas with native plant species. The standard goal is to achieve 70% vegetative cover. As described elsewhere, the revegetative process on the Refuge property has been accomplished using a mixture of grasses beginning in test plots in 2003 and subsequent mechanical seeding using a tractor-spreader and crop duster aircraft through spring 2006.

The planting was highly successful and grass has been established on approximately 90% of the re-vegetation zone (Jennifer Lansing, Arcadis, personal communication, 2009). A number of studies have been conducted by outside groups to independently verify the success of the revegetation efforts on the LGWR property. In 2004, total cover and root analyses were done by the Frank & West Environmental Engineering firm. In 2006, a report on the progress of the revegetation efforts was completed by BBL of Arcadis.[1] In 2007, IR imaging data (done by Aerial Associates Photography, Ann Arbor, MI) to assess vegetative cover was confirmed through field analyses conducted by scientists from Arcadis.

On the steep slope areas, there are boulder-covered areas that appear to be un-vegetated from a distance, but closer inspection reveals grasses sprouting between the boulders to the extent possible for them to grow.

[1] Methods and photos from these studies are included in Appendix A-1 "WIC Ground-Applied Area", Anonymous. 2006. Vegetation Assessment, Palmerton Zinc Pile Superfund Site. Arcadis BBL, Albany, NY.

Two types of areas remained un-vegetated after the 2006 seeding. These include areas of reddish soils and steep slopes between the two rail beds. Several places with the reddish soils derived from Bloomsburg Formation siltstones are difficult to revegetate.

Grasses have slowly established in these areas since planting and now, most of these places are successfully covered. A few places above the LNE Trail (former rail bed) have steep banks from the cut for constructing the rail line, and major erosion ditches (as much as 5 m deep) developed there over the decades. In the past five years, summer interns funded by the Superfund responsible party, CBS, have been working to establish vegetation in these channels caused by erosion. Straw bales placed in the channel created sediment traps and grasses planted there have fully vegetated the bottoms of the channels. In 2009 and 2010, interns have hand-seeded the sides of these ditches in order to attain full vegetation.

The LNE Trail is approximately 100 meters upslope from the Lehigh Valley Railroad bed, which follows the Lehigh River through the Refuge. These two rail beds have become spines of the trail system through the Refuge. The area between these two abandoned rail lines is very steep. Ground-based seed application with the tractor was impossible, and aerial application was too hazardous at this elevation, so the area was seeded to the extent possible by ejecting seed over the bank of the LNE rail bed. This was done in 2006 as part of the full-scale revegetation effort. The seeding was successful, and grasses were generally established on the top 10-15 meters of the slope and are gradually seeding themselves down the slope.

In the intervening years, interns have scattered seeds by hand wherever possible by walking along the slope, but some areas are too steep for safe walking. In 2009, numerous storms with heavy rains drenched the Refuge causing erosion channels to develop in some of these steep, unvegetated slopes between the two rail beds. Interns have addressed this problem by working up from the bottom of the slope, building erosion control walls as they ascend the slope, seeding with compost/lime/grass seed mix. In some places, rocks from the site were also used. These walls, acting like the straw bales, trap the sediment; grass seedlings had established by the end of summer.

An invasive species management plan was developed for CBS by Arcadis BBL.[2] This is a draft plan that was created for public lands east of LGWR. Although it has not been implemented to date, it is being used as the guiding document for the invasive species management plan of the Refuge. This plan calls for workers with backpack sprayers (and hatchets for girdling in the case of tree-of-heaven or *Ailanthus altissima*) to spray herbicide on individual invasive species plants. The most prominent species by far is butterfly bush (*Buddleja davidii*). The other species identified specifically in the plan is tree-of heaven (*Ailanthus altissima*). Other species being controlled to some extent on LGWR property include Japanese knotweed (*Falopia japonica*), Japanese barberry (*Berberis thunbergii*) and alder buckthorn (*Rhamnus frangula*). Several other species were noted in Part I of the ecological assessment and their control in the floodplain and riparian areas was considered a priority. Unfortunately, funding for this management has not become available, since it is not deemed a threat to the re-vegetation efforts required by CERCLA.

In summary, the vast majority of the CERCLA issues have been addressed on the LGNC-owned portion of the Palmerton Zinc Pile Superfund Site. The EPA has not decreed the work complete because they consider the LGWR property as part of Operable Unit 1 (OU1), the Blue Mountain (Kittatinny Ridge), and several hundred acres owned by the National Park Service across the river east of LGWR have not been revegetated to date. The EPA does consider the mechanical re-vegetation work complete at our site, but continues to require the above-mentioned work on the areas where vegetation remains to be established or where new erosion channels form. The Superfund process requires a review every five years after the site is deemed stabilized under CERCLA; the last review was completed in 2007.

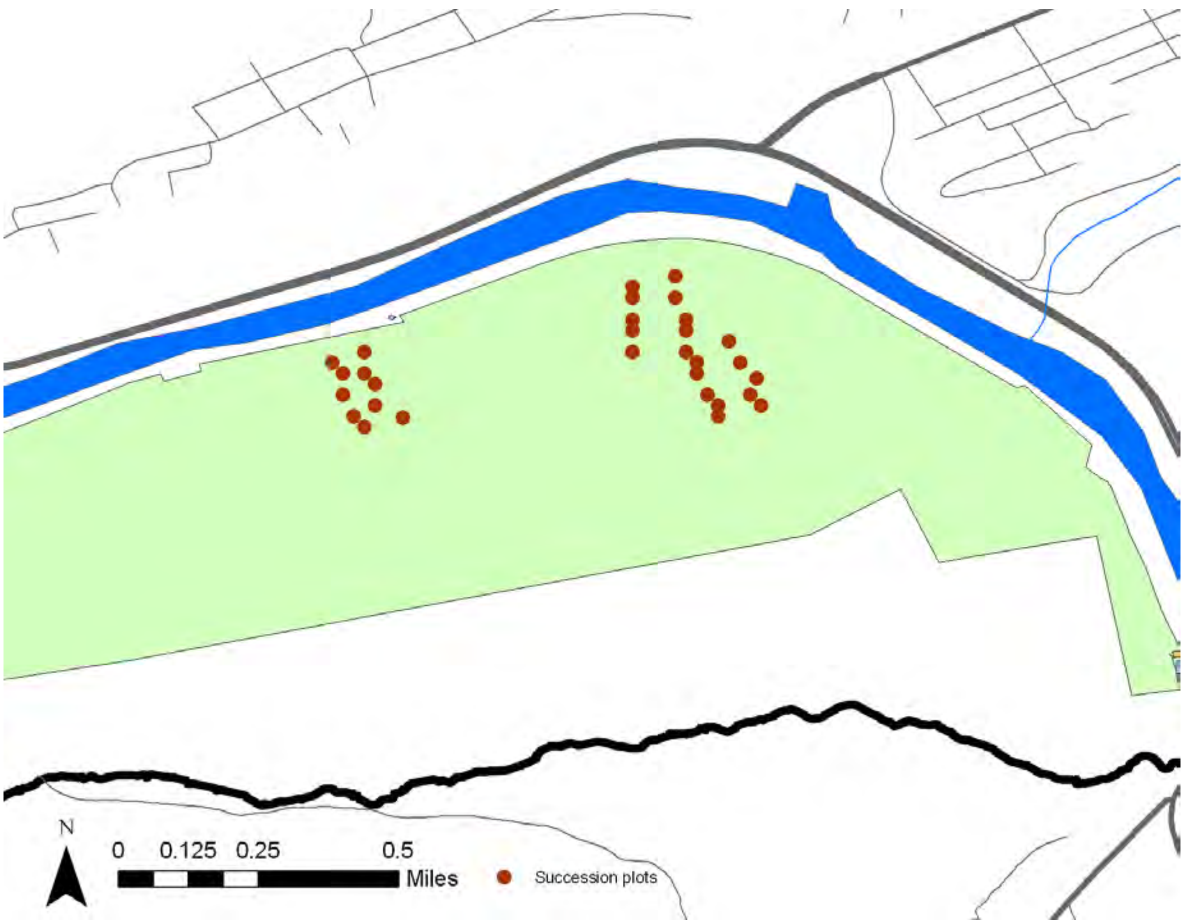
Succession Monitoring

Because the goal of LGNC is to manage the revegetated area as high quality wildlife habitat, it is imperative that the vegetative changes that are occurring on the site be monitored. To this end, with the assistance of Jennifer Lansing of Arcadis, a succession-monitoring plan has been designed and implemented to gather the information needed for adaptive management of the site. This plan is described in a report included as Appendix H-1.

Permanent monitoring transects were established in 2008 in the grassland area (see map below).

[2] Lansing, Jennifer and Kathy Romaine. 2007. Draft Invasive Plant Management Plan, Operable Unit 1, Geographic Area 2. Arcadis BBL, Albany, NY.

Three pairs of 200 meter transect lines were installed using metal posts at 50-meter intervals. Each transect includes a beginning post, an ending post, and three monitoring posts at 50, 100 and 150 meters respectively. The GPS coordinates of the posts were recorded and are found in the report (Appendix H-1).



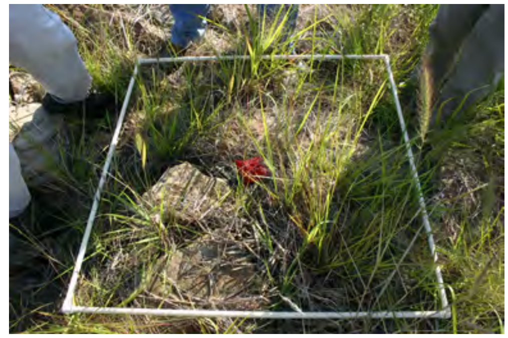
Location of Succession Plot Transect Posts at the LGWR

Three kinds of monitoring are to occur at each transect point – tree monitoring, shrub monitoring, and herbaceous plot percent cover monitoring (details are found in the report in Appendix H-1).

- *Tree plot monitoring.* All trees (defined as one meter or more in height) within a 30-meter diameter circle centered on the monitoring post are identified to species and recorded.

- *Shrub plots monitoring.* All shrubs (defined as multi-stemmed woody plants *and* tree species less than one meter in height) within two randomly selected 10-meter diameter shrub plots are recorded. Whenever possible, shrub species to at least genus level are identified.

- *Herbaceous plot monitoring and percent cover.* Five randomly selected herbaceous plots are monitored (and are different each time). A one-meter square frame is placed on the ground with a randomly tossed beanbag at its center. From a vantage point looking straight down at the plot center, an estimate is recorded for the amount of ground covered by live vascular plants as opposed to ground cover such as bare soil, rock, gravel, or un-decomposed wood.



After the percentage of vascular plants and "non-living" (abiotic material and dead) ground cover are recorded, each must be broken down into its component parts (solid rock, fragmented rock, wood, plant litter, etc.). The types of vascular plant cover are recorded as well (live grass, fern, tree species, other herbaceous plants, etc.). The grass and other plant species are identified when possible and the dominant grass species in the plot is recorded.

Baseline monitoring was completed in 2008 by LGNC staff and interns after the transect lines were installed between August 21 and September 11, 2008. These results (Appendix H-1a) will provide the baseline for future monitoring. In summary, live vegetation covered 49% of the succession plots, with 88% of that live vegetation being the grasses that were planted (accounting for 43% of ground cover). Another 34% was solid rock. Therefore, 83% of the ground surface was covered by live vegetation or solid rock. Of the remainder of the ground that was not vegetated or covered by solid rock, only 4% was soil or gravel.

The dominant grasses in the plots vary from site to site; Canada wild-rye (*Elymus canadensis*), sand lovegrass (*Eragrostis trichodes*), and switchgrass (Panicum virgatum) were the most frequent dominant species. The predominant shrub is the invasive species butterfly bush (*Buddleja davidii*) with young birches (*Betula* sp.) and aspens (*Populus* sp.) contributing significantly to the "shrub" content of the plots. There were an average of 36 shrubs per plot including predominantly butterfly bushes and birch tree saplings or seedlings less than one meter in height. Birches were the dominant tree species recorded, with gray birch (*Betula populifolia*) being predominant followed by black birch (*Betula nigra*), sassafras (*Sassafras alba*), and aspen (*Populus* sp.).

With 83% of the ground covered by solid rock or vegetation, the site can be considered nearly fully stocked with plants. Only a few areas of bare soil remain, mostly the black soil patches, which is extremely high in metals. It has been hypothesized that these black soil sites are partially decomposed organic matter in which decomposition was arrested as metal content (as a percentage of total mass) became too great and killed the decomposers.

The appearance of a significant number of shrubs and trees is an indication that succession is rapidly changing the make-up of the plant community on the site. The vast majority of the trees are native (with the invasive species *Ailanthus altissima* as an exception); however, the predominant shrub is butterfly bush (*Buddleja davidii*), another highly invasive species at this site.

As noted previously, control of *Buddleja* and *Ailanthus* on the Refuge site has been initiated. Based on the preliminary succession plot results, there is now confirmation that this is indeed warranted. The appearance of birches and aspens is a more difficult issue. These native species are pioneers in the natural succession process, but they also take up metals at quantities that far exceed the uptake by the grasses (see below). In addition, they will soon shade out much of the grass and the character of the site will change. Thus, the metal uptake and habitat changes involved with these trees presents a management question of whether woody vegetation should be controlled (arrested succession), perhaps with prescribed burns.

Subsequent succession plot analyses have been performed, but the results have not yet been fully analyzed.

Metal Uptake by Plants

As part of the risk assessment for the site, studies conducted by BBL in 2005 show that the grasses were taking up the metals in concentrations low enough to be deemed safe for wildlife and people.[3] At that time, the recommendation was made that continued monitoring will be needed as site vegetation changes and pioneering trees become a more significant part of the vegetation.

Preliminary studies examining the update of metals by key pioneering tree species, the rare metal tolerant plant *Minuartia patula* (sandwort), and the Pennsylvania endangered *Dicentra exima* (wild bleeding heart) were conducted from 2007 to 2009 by students from Moravian College working with Dr. Diane Husic. The students were also interested in the impact of the metals on plant biochemistry. Key questions included:

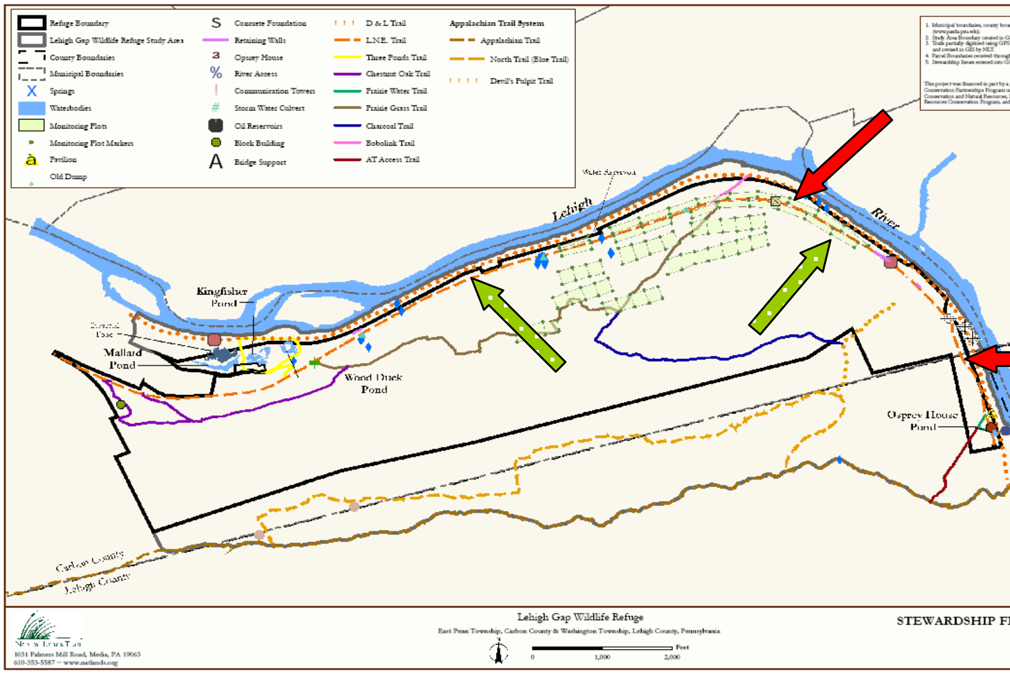
- How are the soil metals affecting the photosynthetic apparatus and capacity in the leaves of various Refuge plant species, some of which show signs of stress such as the gray birch (*Betula populifolia*), and others which seem to be adapting well such as sandwort (*Minuartia patula*) and wild bleeding heart (*Dicentra eximia*)?

- What adaptive strategies are being used by various species to cope with the metals?
  - Are metal binding proteins involved in the physiology of the metal tolerant species mentioned above?
  - Are the metals causing oxidative stress in some of the plant species?

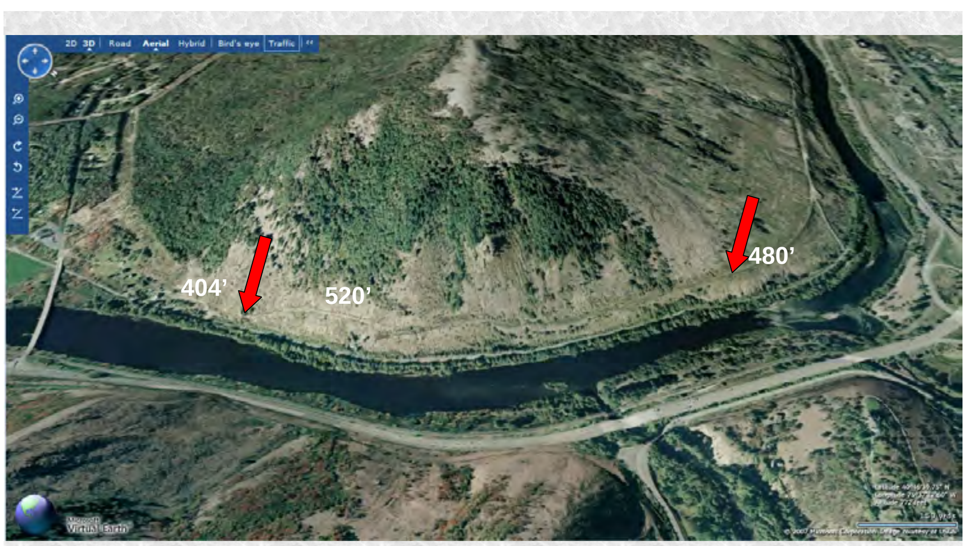
A summary of this research is presented in poster format in Appendix G. This poster was accepted for presentation at the 2009 National Conferences on Undergraduate Research held at the University of Wisconsin, LaCrosse and was selected for the Council on Undergraduate Research Posters on the Hill Event in 2009 where it was presented by Sarabeth Brockley on Capitol Hill.

The map on the following page shows the areas in which plant samples were obtained. Except for sandwort, samples were taken from plants growing along the LNE trail between the red arrows (2007). Sandwort samples were taken from populations growing within the grasslands in the area between the green arrows on the map (2008).

[3] Anonymous. 2004. Preliminary Human Health and Ecological Risk Evaluation and Data Summary Report – Warm Season Grass Remediation Area. BBL, Inc., Annapolis MD.



Maps Showing Location of Plant Sampling for Metal Uptake and Stress Studies at the LGWR



As seen in the table on the next page, a number of pioneering species of trees show elevated levels of zinc in their leaves. This is consistent with the results of previous testing of plant tissues on the LGWR property conducted by scientists from BBL (see reference 3 above). As noted in Chapter 8, the previous sandwort metal uptake studies were conducted by Marilyn Jordan at Rutgers University.[4] Sassafras, a tree that reproduces through vegetative propagation and was one of the few plant species that would occasionally sprout on the property prior to the restoration project, takes up relatively little zinc.

The gray birch appears to be the most dramatically impacted tree species. As noted in Chapter 8, the leaves exhibit severe marginal chlorosis which worsens throughout the growing season. The trees are stunted in their growth and a significant percentage of the leaves complete senesce and drop almost a month earlier than expected.

The leaves of the gray birch showed elevated levels of leaf phenolics (data not included) which is a possible sign of oxidative stress, but these trees are likely drought and nutrient stressed as well. The presence of the high levels of phenolics interfered with protein extraction and, in turn, metal binding protein studies were not conducted in this study. Interestingly, there are reports in the literature that during heavy metal stress, phenolic compounds can act as metal chelators and can directly scavenge molecular species of active oxygen which are more readily formed in the presence of heavy metal ions.[5]

The birch leaves showed other evidence of stress as well. Even upon removal of the chlorotic margins, the stressed leaves had significantly lower levels of chlorophyll per cm^2 surface area or per gram wet weight than leaves from control birch trees. Chloroplasts isolated from the stressed birch leaves were found at a lower density in a Percoll density gradient after centrifugation. They appear smaller and abnormally shaped compared to chloroplasts from healthy (control) birch leaves.

Interestingly, the herbaceous perennial bleeding heart and the annual sandwort show no signs of stress despite the significant accumulation of zinc in the leaf tissue.

One of the stated EPA goals for monitoring includes vegetation health (root development, stem and leaf development, mean nodule number, total dry weight of plant, etc.).[6] Upon maturity of various plants species, monitoring of reproductive potential should be initiated (e.g., seed, fruit, production and viability) to ensure development of seed bank and sustainability of vegetation. Plant tissue concentrations of metals are needed for seeded and volunteer

[4] Jordan, M.J. 1975. Effects of zinc smelter emissions and fire on a chestnut-oak woodland. *Ecology* 56: 78-91.

[5] Michalak, A. 2006 Phenolic Compounds and Their Antioxidant Activity in Plants Growing under Heavy Metal Stress, *Polish J. of Environ. Stud.*, Vol. 15, No. 4 (2006), 523-530.

[6] Personal communication with EPA staff members.

grasses and introduced and volunteer forbs, shrubs, and trees by species. Ideally, this will be correlated with surrounding soil metal concentrations.

Based on the preliminary results described above, the LGNC needs to work with the EPA, the responsible party and others to develop a management plan for pioneering species that accumulate heavy metals so as to minimize the remobilization of the metal contamination be it through direct herbivory or falling leaves containing metals being blown to new locations including the Lehigh River or ponds where they can become a food source for macroinvertebrates.

Zinc Levels in Leaves from Selected Plants at the LGWR Property

Plants sampled	Leaf zinc levels from LGWR studies (2007-08)	Literature values for zinc levels in plants within the Palmerton Superfund site*	Levels of observed plant stress
Tree species	**ppm**	**ppm**	
Gray birch	1086 ± 390 (n = 21)	330 - 1800	Severe
Sweet birch	n.a.	1000 - 3200	High
Quaking aspen	n.a.	500 – 1100	Minimal
Big tooth aspen	2200 (n = 1)	n.a.	Minimal
Aspen spp.	n.a.	2400	
Sassafras	290 (n = 1)	40 - 800	Moderate
Other plant species			
Wild bleeding heart	760 ± 10 (n=3)	n.a.	Negligent
Sandwort	3300 ± 1400 (n= 18)	Up to 15,000	Negligent

*See references 3 & 4 in text. The literature values for zinc levels in leaves in this table are updated from that in Appendix G to include some metal uptake values reported from more recent studies conducted by Arcadis.

Studies of Ecosystem Function

As part of the 2004 risk assessment work conducted by BBL, food web modeling was conducted using exposure point concentrations calculated from the September 2004 soil and vegetation data and general dose equations from the Wildlife Exposure Factors Handbook.[7] The models provided estimates of the potential average daily dose (in mg/kg-day) from dietary exposure and incidental ingestion of soil. Several types of ecological receptors were evaluated, including herbivores (e.g. meadow vole, white-tailed deer, and field sparrow), insect-eating species (e.g., short-tailed shrew and American robin), and carnivores (e.g., red-tailed hawk and red fox). The results of the ecological evaluation indicate no ecological risk for most of the receptors evaluated. A low risk was estimated for American robins; however, the uncertainty associated with the robin assessment was high given the lack of earthworms (their preferred food source) within grassland remediation area and the lack of site-specific bioaccumulation data. To this day, earthworms have not been found in the soil in the remediation area or in soil samples taken from along the LNE trail (e.g. between the red arrows in the map on page 9-9).

With succession and the enhancement projects, it is of interest to know more about the impact of plant introductions (intentional, spontaneous succession, invasions by alien species) on processes central to the ecology and biotic communities of the grassland. These plants are potential novel food sources and as such, such be monitored for folivary, nectarivory/pollination, and seed predation.[8] If seeds are being eaten, this is a new mechanism of seed dispersal for the site, and if these seeds contain heavy metals, it is also a new means of redistributing the contamination. The new plants also provide nest sites and cover and as described by Aslan and Rejmánek "altered spatial distribution in response to altered resource patterns" (i.e. altered migration patterns).[7]

Currently, John Reese, a Moravian College student is working on an herbivory project involving several native and invasive species, including butterfly bush (*Buddleja davidii*), at different locations within the Refuge. Reese is examining the types and numbers of insects that he captures on different plants and is scanning leaves and then using a program called NIH Image to quantify herbivory levels. Ideally, a field-based leaf area scanner and software can be acquired in the future to enable measurements of herbivory levels and leaf damage without removing leaf samples. This allows the research to return to the same leaves in the field to measure

[7] USEPA. 1993. Wildlife Exposure Factors Handbook. EPA/600/R-93/187a. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

[8] Aslan, C.E. and M. Rejmánek. 2010. "Avian use of introduced plants: Ornithologist records illuminate interspecific associations and research needs", *Ecological Applications* 20(4): 1005-1020. This research is interesting in that it involved extensive use of citizen scientists.

changes in size, herbivory, damage, etc.

A new food web study was initiated at the Refuge under the direction of Drs. Ned Fetcher, Ken Klemow, and Michael Steele from the Wilkes Institute for Environmental Science and Sustainability at Wilkes University. Although warm season grasses are becoming established at the Lehigh Gap Wildlife Refuge, it is not known whether other organisms are using these grasses as a food source. Warm season grasses possess the C_4 photosynthetic pathway which produces different proportions of the stable isotopes ^{12}C and ^{13}C than the C_3 photosynthetic pathway found in the vegetation surrounding the site. As a consequence, organisms that consume warm season grasses will have a different isotopic ratio of ^{13}C to ^{12}C than organisms that consume trees, shrubs, forbs, and grasses with the C_3 pathway. Organisms that consume tissue from both groups will have isotopic ratios that are intermediate between the ratio for C_4 plants and that for C_3 plants.

In summer of 2008, Wilkes undergraduate students Jeff Stratford, George Haleem and Rachel Curtis collected samples including invertebrates as well as hair and feathers from vertebrates at two sites in the Refuge – one with primarily warm season grass cover and the other with trees and ferns. In the grassland area, most of the above ground plant biomass is from warm season grasses at this point. Birds were trapped in mist nets and feather and fecal samples obtained. Small mammals were trapped and feces samples and a small amount of tissue from the ear were taken. The invertebrate samples are awaiting identification, but the vertebrate samples have been analyzed.

Two bird samples, three small mammal samples, and a shed skin from a rat snake were taken from the warm season grass site. All of the small mammals, two meadow voles (*Microtus pennsylvanicus*) and a deer mouse (*Peromyscus* sp.), have isotopic ratios similar to those of warm season grasses. However, the ratios for the birds and the snake on the warm season grass site are much closer to the ratio for C_3 plants (i.e. the carbon did not come from warm season grasses). On the tree and fern site, only one of the four bird samples and none of the two small mammal samples showed evidence of consumption of C_4 plants. At this stage it appears that the warm season grasses are having somewhat limited impact on the food web of the Lehigh Gap Wildlife Refuge, but this conclusion is extremely preliminary. The plans are to continue and expand the study to include more invertebrate, vertebrate and fecal sample.

Worm-eating Warbler Captured During Mist Netting

Habitat changes and disturbances

Due to site work over the past several years, there have been a number of areas within the Refuge that have been altered. In order to make trail improvements, the D&L Trail was widened in 2006 and then East Penn Township cleared a significant amount of brush from the trail edges in 2008. This temporarily removed some invasive shrubs as noted in Chapter 8, but also removed habitat, including potential food sources for birds and animals. During bird surveys, fewer sparrows, catbirds, and migrating warblers were noticed in these areas after the clearing. During this work, some trees were removed along the trail close to the bottom of the Bobolink Trail in an area where Blue-gray Gnatcatchers had nested previously. To date, this nesting species has not returned to that region of the Refuge. In order to decrease puddle formation in the trail, especially in the area of seeps, drainage systems were installed. This is an improvement for people using the park for recreation and for trail maintenance, but decreased the number of pools for Pickerel Frogs and American Toads which routinely used the puddles for laying eggs and tadpole development.

In the process of improving the drive around the Osprey House and in preparation for construction of the new Visitor and Education Center, a significant amount of trees and brush was cleared between the Osprey House and the pavilion in 2007. This had been a gathering spot for migrating and winter birds. However, new native plant gardens were installed in this area in 2010 which should provide new forms of habitat and an outdoor classroom for visitors. These types of ecological disturbances can not be avoided on a property with mixed uses that include recreational opportunities for the public.

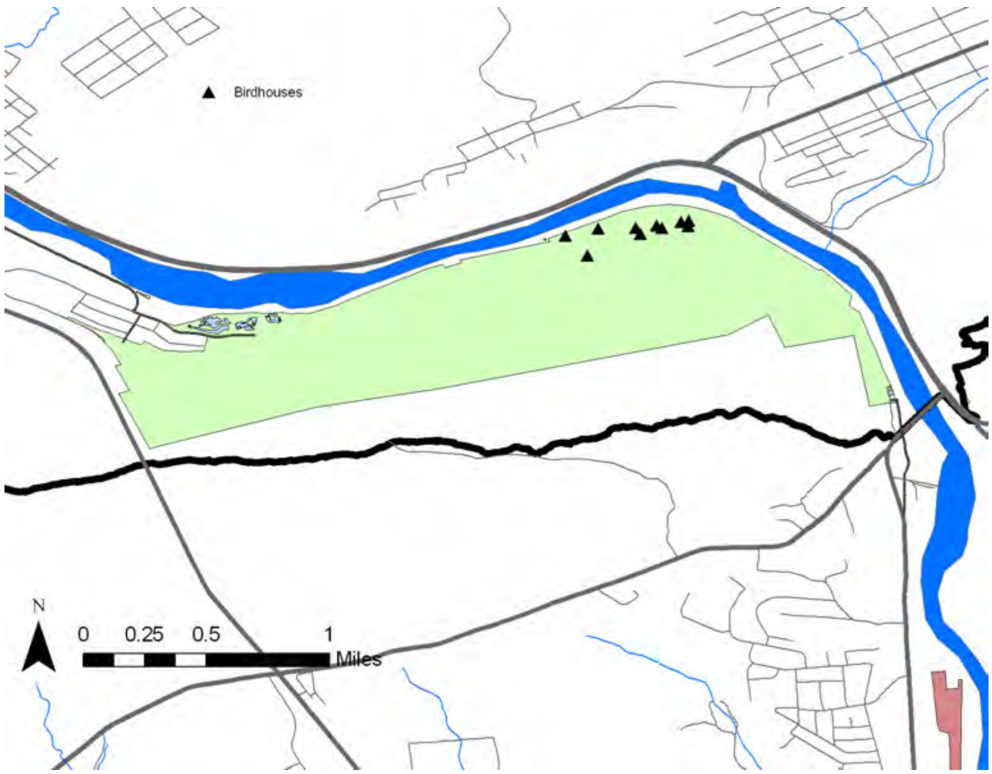
The popularity of the Refuge is growing as evidenced by the number of visitors to the Center. With increased trail use, there is increased risk of disturbance of plants (trampling) and for the introduction of alien species or disease brought in on hiking shoes or vehicle tires. Careful monitoring will be required.

There are a number of ravines throughout the Refuge – many of which likely originated from erosion, run-off, or springs (see map on the next page). Because each ravine has a "unique character" in terms of its array of plant species and microclimate, it will be interesting to monitor succession in these areas in the future. One ravine, Smilax Hollow, is the farthest point west where significant patches of sandwort (*Minuartia patula*) are observed (as noted in Chapter 8). Grosbeak Gulch is the site of the first breeding record

for Blue Grosbeak (*Passerina caerulea*)
in Carbon County (see Chapter 5).

The Ravines of the Lehigh Gap Wildlife Refuge

Some changes within the Refuge actually enhance diversity such as the addition of nesting boxes in the grassland area (see Map below). Six American Kestrel boxes (in the grasslands and along the D&L Trail); three Wood Duck boxes (in the area of the ponds); and more than 20 additional Bluebird boxes (around the Osprey House and Prairie Warbler Trail) have subsequently been installed.



Location of Initial Bluebird Nesting Boxes Installed in the Grasslands at the LGWR

Linking Ecological Studies and Conservation with the LGNC Education Mission

Many of the studies described in this report have involved citizen scientists. These public participants are able to learn while doing; they provide valuable contributions to the large scale monitoring and habitat enhancement projects; and they gain a deeper appreciation for the restoration miracle that has happened at the Refuge. The LGNC benefits from this public participation in that the vast amount of work that has been accomplished would not have been possible without a lot of volunteers, since financial resources are not sufficiently available to hire enough scientists and interns.

As news spreads about the successes, outside groups are approaching the LGNC to participate. One example is the Service Learning in Public Policy (SLIPP) program run by the Freedoms Foundation at Valley Forge, PA (http://www.freedomsfoundation.org/SLIPP-main.cfm). Jason Raia, the director of this organization, contacted the LGNC to see if the high school student participants with an interest in environmental policy could visit the site in order to learn about Superfund legislation and its applications at the Lehigh Gap and participate in some meaningful service learning project. He met with Dan Kunkle and Diane Husic and did a site visit of the Refuge in June and decided it would fit their program goals.

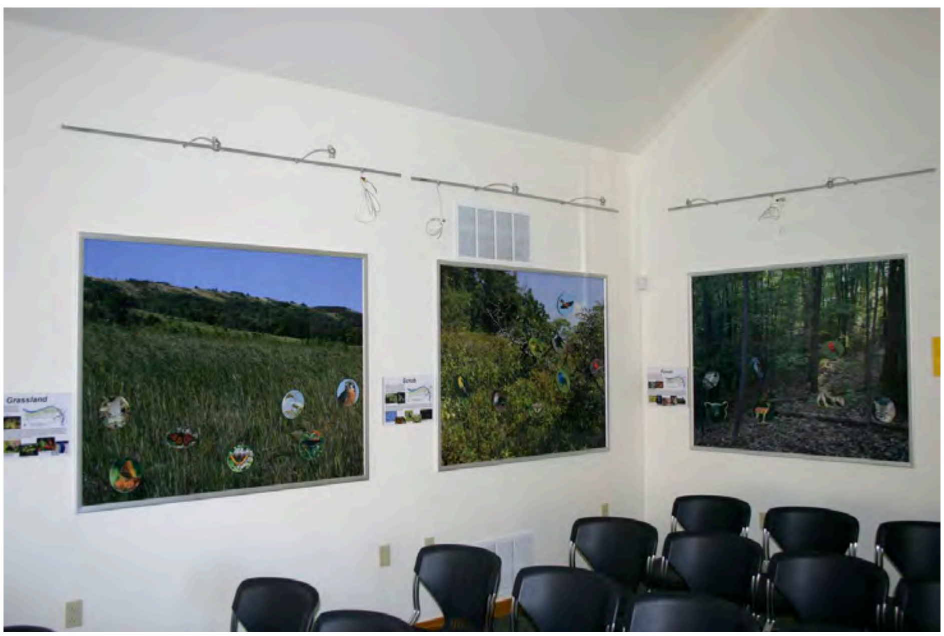
On July 20, 2010, eight students and two adult councilors came to the Refuge. The day began with an introduction to CERCLA and the LGNC projects. The students then participated in succession plot monitoring collecting important data for this project for the 2010 database. The following day, Diane Husic was invited to speak to the entire group of SLIPP participants at Valley Forge on Environmental Leadership. (The Fall 2010 Ecology Class at Moravian collected another set of succession plot data on October 1st.)

Collecting data for these research plots for succession is time-consuming and requires the ability to identify plants. Some of the plots (transect posts) are also at sites that are relatively difficult to reach. However, the educational value of such monitoring is high. As a result, another succession plot for teaching purposes was established (see Appendix H-2).

The results of these ecological studies and this assessment project are being used in other ways to enhance the educational programming of the LGNC. Mapping that was done for this project, in conjunction with photographs of habitat and species representing the diversity of the Refuge, was used to create educational displays for the Osprey House addition (the new visitor center and education building) at the LGNC. A series of photos of these displays are included at the end of this chapter and downloadable files of the habitat descriptions for these displays are included as Appendix J-1 to J-6. Educational signage has also been created for the outdoors; example of signs for the habitat gardens is included at the end of the chapter.

Bioacoustics Survey: Wildlife Vocalizations at Lehigh Gap Nature Center

People interested in nature often utilize field guides to identify plants and animals visually, but it is difficult to access guides for learning vocalizations. Without good resources to learn these vocalizations, people are missing an important aspect of the natural world. In this project, Corey Husic has begun to record the vocalizations of the wildlife species known to exist at the Refuge and create a field guide to these vocalizations. This guide will be available on the Lehigh Gap Nature Center web site (see Sound Field Guide at http://lgnc.org/resources/soundguide) and can be downloaded for use on a portable mp3 player or other electronic device. To date, sample recordings for some amphibians and birds are available.



Habitat Educational Display at the Osprey House at the LGWR

Habitat Educational Displays at LGWR

Examples of Educational Signage for the Habitat Gardens