

Chapter 12

Conclusions: Reflections and Recommendations



Reflections and Recommendations

“Ecosystems are not only more complex than we think; they are more complex than we can think” (Egler 1977)

“Change is inevitable. Change is constant”
Benjamin Disraeli (1800s)

Change: Embracing our History and Meeting Contemporary Challenges

While Disraeli¹ was referring to social and political change, his statement is also quite applicable to our environment. Given the choice, many humans are adverse to change, but ironically, we inflict a tremendous amount of change upon the world around us, including the natural world. The property known as the Lehigh Gap Wildlife Refuge has undergone a tremendous amount of this human-induced change from decades of zinc smelting operations in the area. But now, the site has undergone another remarkable transformation and the Refuge has become a model of revitalization for other sites contaminated with heavy metals. The in-depth ecological assessments that have now been completed and the role of volunteers and citizen science that the LGNC has relied on are also examples of effective practices. The LGNC has developed a diverse collaborative team of highly knowledgeable researchers and practitioners who collectively now have expertise in

reclamation work, threatened habitats, and mixed-use conservation practices. The LGNC website (www.lgnc.org) was completely revamped in 2009 to be a resource to not only researchers, but perhaps, more importantly, the general public. It houses the stories of change and restoration; the LGNC history; the ecological assessments and a number of other resources; and the organization’s conservation, research and education goals. The changes that have transpired since 2002 at the Lehigh Gap and within the organization are nothing short of remarkable.

A number of individuals involved with the LGNC have studied documents and other resources from state and federal agencies and the scientific literature (where available) to guide their work during this second phase of ecological assessment and to begin determining the next phase of conservation management plans for the Refuge. To better understand the history of the Lehigh Gap, the Palmerton Superfund Site and the work done at the Refuge, in the summer of 2009, Meredith Wright, a student from Moravian College, compiled the “Annotated Bibliography of Sources Written about the

¹ (1804-1881) 1st Earl of Beaconsfield, British Prime Minister, Parliamentarian, British Conservative statesman and literary figure.

Palmerton Zinc Pile Superfund Site and Lehigh Gap.”² The bibliography is 212 pages long and contains over 500 entries. It is a valuable resource for the EPA, the borough of Palmerton, including the library where many of the resources are stored (and organized now thanks to Ms. Wright), and those interested in either historical or scientific research related to the Lehigh Gap.



**Meredith Wright with Diane Danielson,
Director of the Palmerton Library**

The “R” Words of Restoration

Another Moravian student, Sarabeth Brockley, conducted an investigation into the science of ecological restoration and the concept of adaptive management—the latter being an alternative approach to natural resource management developed in the 1970s. A portion of her work is included in the discussion below. During the time period during which Part II of the assessment was worked on, there have been many relevant discussions related to restoration and management goals; thus, it seems appropriate that some of these discussion themes be included in this section of the report to share what has been learned and

² Available on the LGNC website at <http://lgnc.org/resources/reports>.

for others to see some of the issues we have grappled with.



Sarabeth Brockley

The Society for Ecological Restoration (SER) defines ecological restoration as “the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed.”³ The phrase “*assisting the recovery of an ecosystem*” is important to note since it has been the approach of the LGNC to find nature-based solutions (versus technology-based ones) to challenges presented from decades of zinc smelter pollution. The belief was that metal-resistant grasses might have eventually re-established themselves on this site, but would have taken a long time. Thus, the plan was to assist nature through the planting of the grasses. More recently, there has also been a deliberate and carefully thought-out project to enhance the plant diversity within the developing grassland as described in this report (Chapter 8). A

³ See http://www.ser.org/content/ecological_restoration_primer.asp.

future challenge will be to decide the next steps which could mean arresting the natural process of succession (see below) which veers away from the idea of letting nature take its course.

The LGNC has often been involved in discussions of whether we have actually been involved in restoration or reclamation or a number of other “R” words that are used. The following descriptors are adapted from the text, Principles of Conservation Biology (2006)⁴ and Walter, *et al.*⁵.

1. **Reclamation** is referred to as a *revegetation or land management goal that includes a lower diversity of species and may include substitutions by introduced species*. Walker *et al.* define reclamation as “the conversion of wasteland to some productive use by conscious intervention”. Clearly, the LGNC project has involved reclamation work.
2. **Re-creation** defines the *act of entirely reconstructing a site denuded of its terrestrial and/or aquatic systems. This commonly occurs on surface mined lands and in brownfields* (severely damaged urban and industrial lands). Sometimes this is also referred to as creation, but this implies transforming a site to a completely

⁴ Groom, M.J., G.K. Meffe, and C.R. Carroll 2006 Principles of Conservation Biology, 3rd ed., Sinaur Associates

⁵ Walker, L. R., Walker, J. and Hobbs, R.J. eds. 2007. Linking Restoration and Ecological Succession. Springer

different ecosystem than had previously existed on the site. Given that a significant portion of the Refuge was completely denuded from the zinc smelter process, there has been a re-creation of an ecosystem.

3. **Rehabilitation** looks at the *creation of an alternative ecosystem following a disturbance, different from the original and having utilitarian rather than conservation values*. The primary goal is to raise ecosystem productivity for the benefit of people. Walker *et al.* defines rehabilitation quite differently “as any manipulation of a sere to enhance its rate or to deflect its trajectory towards a specified goal;” a sere is a sequence of ecological communities that occur in an area during stages of succession. Clearly, the work done at the Refuge enhanced the rate of recovery from the denuded condition. The specified goals include those of the EPA’s Record of Decision aimed at minimizing current and future risk to humans and the environment (i.e. the purpose of the CERCLA or Superfund legislation). However, the LGNC has also been involved in developing a site that can be used by people once again for both recreation and education. In this sense, this work has indeed been for utilitarian purposes and could be labeled rehabilitative.
4. **Reintroduction** attempts to *establish a species in an area which was once part of its historical range, but from which it has been*

extirpated or become extinct. From a) analyses of serpentine barrens (with soils naturally high in metals) and models of post-glaciation recovery; b) historical accounts of both practices of the native peoples and the existence of a hairgrass-lowbush blueberry savanna on Blue Mountain around Lehigh Gap⁶; and c) the presence of the native grassland on the top of the ridge that existed prior to the restoration work, the plan to *reintroduce* native grasses to establish a grassland was a logical approach for the revegetation efforts.

5. **Remediation** deals with the *removal of toxicants from a contaminated environment using chemical, physical, or biological means.* The EPA Record of Decision does not include plans for removing the contaminating metals from the site, but rather immobilizing them in the soil so that they no longer represent a risk. Removal would have been technically impractical and cost prohibitive. The work that has been done at LGWR is aligned with this decision.
6. **Restoration** refers to *the process of using ecological principles and experience to return a degraded ecological system to a more ecologically functional state. The goal of this process is to emulate the structure, function, diversity,*

and dynamics of the specified ecosystem. Walker *et al.* describe restoration as the “manipulation of a disturbed habitat or landscape to a desired condition.” Clearly the creation of a thriving ecosystem on a once denuded site represents *restoration*.

7. Walker *et al.*³ includes a 7th “R”—**resilience**—a term that is showing up more frequently in the literature, especially in terms of climate change adaptation. Resilience is defined as *the capacity to recover following disturbance.* It is not expected that industry will return to the region but future disturbances are likely due to human impact on the Refuge including: recreational use, disruption due to construction and trail upgrades, the spread of invasive species, and climate change. Any future management plan must involve ongoing monitoring for signs of new human-induced disturbances, including impacts of climate change. Large scale disturbances caused by severe erosion, redistribution of the contaminants, etc. certainly have been minimized by the revegetation efforts. It is yet to be seen if the grassland is sustainable, or whether succession events lead to new problems. Nonetheless, enhancing *resilience* is an important goal at the Refuge.

A question that often comes up sounds simple enough: “Restore to what?” Should the goal be to restore the mountainside to the conditions of the site prior to the damage caused by the zinc smelting? Reports by Rehn (1903)⁴ and images from old post cards actually provide a glimpse as to what that condition might have been.

⁶ Rehn, J.A.G.. 1903. Notes on the Summer Birds of Lehigh Gap, Pennsylvania. *Cassinia* 7: 11-16; see also the LGWR Ecological Assessment, Part I, pp. 22-26.

Others might suggest that restoration goes back to what conditions were before European settlers arrived. The earliest white visitors to the Lehigh Gap were the Moravian Missionaries in the 1740s and a few settlers such as the Nicholas Oblinger family in 1751.⁷ Historical accounts such as those of the Moravian Missions (in the Moravian Archives in Bethlehem but written in Old German) and the History of Carbon County⁸ describe aspects of the natural environment and the “wildness” that existed north of the “Blue Ridge”. However, due to the introduction of chestnut blight fungus (*Cryphonectria parasitica*) around 1900 and woolly adelgid (*Adelges tsugae*) in the 1950s, and the heavy metals deposited for 80 years, it is highly unlikely that the mountainside can be restored to a chestnut-hemlock forested “wildness”.

Discussions on what “native” means, in terms of plant species to introduce to the Refuge and add to the gardens, have been equally complex and quite spirited. Countless resources on this topic were used to attempt to define this controversial term. As noted in Chapter 8, native has been defined for the habitat gardens at the LGNC as plants native to the mid-Atlantic region, along with commercially available cultivars of native species. Most of the grasses used in the re-vegetation work are native to the region; however, several grass species

that were able to start the remediation process, such as sand lovegrass (*Erogrostis trichodes*) are native to North American, but not to eastern Pennsylvania. These bridge species flourished in the first season of growth and helped create conditions in which the locally native grasses could thrive. As predicted, these “bridge species” are diminishing each year and have not spread from the site. Now that vegetation has been re-established on the barren mountainside, a more stringent definition is being adhered to for the enhancement species being introduced to the grassland. All of the enhancement species are native to eastern Pennsylvania.

The work at the Refuge has no fixed end-point; as with nature, the ecology of the site continues to evolve. The LGNC views this as a long-term experiment with the hope of developing a safe, high-quality habitat that will be self-sustaining for the long term. The two parts of the ecological assessment that have now been completed provide important information on the status of biodiversity (the “baseline” species inventory at the Refuge), succession, the impact of habitat enhancement efforts, herbivory, and environmental risk to humans and wildlife. This information is essential for moving forward with sound conservation management practices and future research.

Redevelopment of Superfund Sites

Although the Comprehensive Environmental Response, Compensation, and Liability Act of

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<http://freepages.genealogy.rootsweb.ancestry.com/~oplifam/Second%20Generation.html>

⁸
http://freepages.genealogy.rootsweb.ancestry.com/~carbdat/m&h/ch_2.htm

1980 (CERCLA or Superfund legislation) was signed into law 30 years ago, the concept of **redevelopment** of Superfund sites – returning the land to productive use – has really only been around since the late 1990s. Industrial parks, shopping centers, recreational areas or sports fields are the typical examples of redevelopment. If a site is simply categorized as “under control” (i.e. the site hazards are contained and risk to humans and wildlife minimized) but left as a vacant, fenced off area, then the land has no value and cannot contribute to a municipal or county tax base. Thus, recycling these sites has gained significant interest. As of the end of 2010, the cumulative total of Sitewide Ready for Anticipated Use (SWRAU) was 585 (51 were in Pennsylvania), with a target of adding 65 additional sites in 2011. However, at the end of 2008 only about 130 of the then 343 SWRAU sites had been recycled.^{9,10}

Even more progressive than the goal of recycling Superfund sites, is the focus on **ecological** reuse – returning

“polluted or otherwise disturbed lands to a functioning and sustainable use by increasing or improving habitat for plants and animals”.¹¹ The EPA defines **ecological revitalization** as “the process of returning land from a contaminated state to one that supports a functioning and sustainable habitat”.¹¹ In the 2006 EPA strategic plan, there was an objective of enhancing science and research under the goal of land preservation and restoration:

“... provide and apply sound science for protecting and restoring land by conducting leading-edge research, which, through collaboration, leads to preferred environmental outcomes.”¹²

This new standard no longer limits the Superfund remediation goals to minimizing risk and controlling the migration of contaminants, but goes further to attempt to convert contaminated areas into functioning ecosystems. This paradigm shift may also involve some radically different approaches – relying less on cutting-edge technology and looking more to nature for solutions.¹⁰

The LGWR is not one of the 51 SWRAU sites because it is part of a

⁹ United States. EPA. Sitewide Ready for Anticipated Reuse – Measure Outcome Highlights. Available at <http://www.epa.gov/superfund/programs/re-cycle/effects/swrau.html>. Updated December 17, 2010. Accessed January 7, 2011.

¹⁰ United States. EPA Report. Ecological Revitalization: Turning Contaminated Properties Into Community Assets. Washington: February 2009. Available at http://www.clu-in.org/download/issues/ecotools/Ecological_Revitalization_Turning_Contaminated_Properties_into_Community_Assets.pdf. Accessed January 7, 2011.

¹¹ EPA. EcoTools: Tools for Ecological Land Reuse. Available at <http://www.cluin.org/ecotools/>. Updated April 29, 2009. Accessed July 23, 2009.

¹² United States. EPA Strategic Plan. GOAL 3: Land Preservation and Restoration. Washington. September 30, 2006. Available at: http://www.epa.gov/ocfo/plan/2006/goal_3.pdf. Accessed July 23, 2009.

larger operable unit of the Palmerton Superfund site—not all of which has been restored to the same degree (i.e. met the EPA’s Record of Decision goals). However, the restoration work at the Refuge is completely consistent with the new ecological reuse goal of the EPA. With this new national emphasis on ecological reuse of contaminated sites and the results documented in this assessment, the LGWR project should indeed emerge as a national model of success. The large increase of use of the site for recreation (including the trail system and river), the interest in the restoration of the site that leads to visitors not only from the region, but also from international destinations, and the frequent visits to the site by researchers all have an economic impact on the local communities surrounding the LGNC (Palmerton, Slatington, and Lehighton). Without the restoration successes, this increased public use of the site or the regional economic benefits would probably not have occurred.

Adaptive Management:

Given the complexity of this project, the lack of precedent projects to learn from, and the remaining uncertainties, the best approach for managing the site is known as adaptive management.

Perhaps the best concise definition of adaptive management is *learning by doing*; it is a process that assumes that “scientific knowledge is provisional and focuses on management as a learning process or continuous experiment where incorporating the results of previous actions allows

managers to remain flexible and adapt to uncertainty” (Grumbine 1997).¹³ The Department of Interior describes this approach in more detail:

Adaptive management [is a decision process that] promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process. Adaptive management also recognizes the importance of natural variability in contributing to ecological resilience and productivity. It is not a ‘trial and error’ process, but rather emphasizes learning while doing. Adaptive management does not represent an end in itself, but rather a means to more effective decisions and enhanced benefits. Its true measure is in how well it helps meet environmental, social, and economic goals, increases scientific knowledge, and reduces tensions among stakeholders (Williams et al. 2009).¹⁴

¹³ Grumbine, R.E. 1997. Reflections on “What is ecosystem management? *Conservation Biology*. 11(1): 41–47.

¹⁴ Williams, B.K., R.C. Szaro and C.D. Shapiro. 2009. [Adaptive Management: The U.S. Department of the Interior Technical Guide](#). Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC. p. 84; available at <http://www.doi.gov/initiatives/AdaptiveManagement/TechGuide.pdf>.

In other words, the process of decision making is based on science, but does not wait until the information is complete. Decisions are made and acted upon, the impact is monitored and further experiments may be conducted, and then the management goals and decisions may be modified. Natural systems are more complex (and less well understood) than controlled laboratory experiments and this is particularly true at a site like that at the Refuge. Few comparable restoration projects exist, and the revegetation efforts began less than ten years ago; thus, there is much uncertainty in the LGWR restoration project moving forward. As Doremus noted, details of the adaptive management process can vary widely “depending upon management goals, the extent of (and gaps in) available information, funding and personnel resources”.¹⁵

According to Lessard¹⁶ and Macey¹⁷ the components of adaptive management include:

- **Assessment** – understanding the current ecological conditions;
- **Scenario planning** – identifying the “critical uncertainties” and designing a monitoring and evaluation system to track decisions;
- **Goals and objectives** – using assessment to assign values to current conditions and describe desired future ecological conditions;
- **Hypothesis development** – creating an experimental design (to reduce uncertainty and benefit from it) and preparing to implement that experiment; and
- **Monitoring and evaluation** – determining what information should lead to changes in policy or goals.

The two ecological assessments will allow the LGNC to move forward in this progression. Macey¹² notes that it is particularly important to garner public support and a sense of ownership for the next set of goals that are developed. And as with the periodic monitoring required of any Superfund site, the assessment and monitoring of the Refuge will also be long-term. It has been surprising to learn how limited the monitoring associated with other restoration work has been as pointed out in a new review by Brudvig.¹⁸

¹⁵ Doremus, H. 2001. Adaptive Management, the Endangered Species Act, and the Institutional Challenges of ‘New Age’ Environmental Protection. *Washburn Law Journal* 41(1): 50-89

¹⁶ Lessard, G. 1998. An Adaptive Approach to Planning and Decision-making. *Landscape and Urban Planning* 40: 81.

¹⁷ Macey, G.P. 2007 “The Promises and Pitfalls of Adaptive Site Management” In Reclaiming the Land: Rethinking Superfund Institutions, Methods and Practices, G.P. Macey, and J.Z. Cannon, eds., Springer.

¹⁸ Brudvig, L.A. 2011. The Restoration of Biodiversity: Where Has the Research Been and Where Does it Need to Go? *Am. J. Botany* 98(3), in press.

Cooke and Johnson (2002)¹⁹, in a review paper on ecological restoration on contaminated mine sites, noted that:

*... efforts to reduce ignorance and uncertainty (through ecological research and experimentation) are necessary.... The essential role of monitoring and management are emphasized, as the uncertainties in restoration planning can never be overcome. The concept of adaptive management and the notion that a restored site be regarded as a long-term experiment gives a sensible perspective for the restoration paradigm.... **Unfortunately, in practice, the lack of post restoration monitoring has meant that failures have gone unnoticed or have been ignored and few lessons have been learned to improve practice** (emphasis added).*

In the foreword to a book entitled Reclaiming the Land: Rethinking Superfund Institutions, Methods and Practices, Marianne Horinko, Executive Vice President, Global Environment and Technology Foundation, writes

I want to underscore that the EPA's primary responsibility is to protect human health and the environment and the future of Superfund must advance this objective as it always has. There must be monitoring mechanisms in place that allow for

real oversight so that site use remains protective and land use controls are adhered to. However, there must also be flexibility inherent in the process so that the EPA can make informed decisions to modify directives so that the process respects changing land use patterns and community needs. ... Where there are private parties willing to contribute resources to the cleanup effort, the EPA needs the agility to rethink its cleanups or components of those cleanups. This agility will lead directly to quicker community revitalization while placing less strain on public funds.

Macey¹² points out a number of challenges of using an adaptive management approach at Superfund sites undergoing restoration. They include the involvement of a range of stakeholders including citizens, government agencies and responsible parties – each of which will have new roles and responsibilities than previously considered in EPA policy. There are few models for how these groups should work together, how administrative boundaries can be smoothly crossed, or how to apply adaptive management to large restoration sites. And the science of systems dynamics and ecological resistance is limited, and even less is known about how this factors into human-constructed revitalization efforts and management models is limited.

The LGNC project has been an example of a partnership between the EPA, the responsible parties, state agencies, scientific researchers, and

¹⁹ Cooke, J.A. and M.S. Johnson. 2002. Ecological restoration of land with particular reference to the mining of metals and industrial minerals: a review of theory and practice. *Environ. Rev.* 10: 41-71

private citizens coming together to address major cleanup and ecological rehabilitation hurdles.

Desired Future Condition Analysis

One of the steps of adaptive management is the development of goals and objectives in which (as noted above) ecological assessments are used to describe desired future ecological conditions. Roger Latham, who has extensive experience in this area (and was a significant contributor to the Ecological Assessment-Part I) pointed us to a definition of ***desired future condition analyses*** that he wrote for the PA DCNR:

Desired future condition (D.F.C.) analyses are part of an emerging science-based approach to ecosystem management by the U.S. Forest Service, National Park Service, and other large-scale land management agencies. The process ties together adaptive resource management, ecological restoration, integrated planning, ecosystem monitoring, and condition reporting. A desired future condition analysis may be defined as a qualitative and quantitative description of ecosystem attributes that are expected to be present at some point as an outcome of deliberate management policies, strategies, and practices. Ecosystem attributes include individual resources, communities, ecosystems, and the natural processes that sustain them. ... A desired future condition analysis is not an attempt to return to the past. It takes into account

*both what is known about the predegradation condition and important influences that are beyond managers' control, for instance, introduced diseases and pests that are now endemic, extinct animals and plants or those that have been extirpated but are impractical to reintroduce, and climate change.*²⁰

Latham also referred us to the technical document on “Desired Conditions for Natural Resources” used by the National Park Service.²¹ In this document, there is acknowledgement that there are three dimensions that go into a desired future outcome including a 1) ***resource dimension*** (ecological integrity, research data, etc.); 2) ***human dimension*** (values, perspectives and responsibilities); and 3) an ***institutional dimension*** (laws, policies and capacity). There are specific relationships and overlaps amongst these dimensions; a sound management practice tries to find “the optimal solutions when management for one dimension without consideration of others would have unacceptable detrimental impacts.” This, of course, requires compromise and tradeoffs among the three dimensions. Given that the Refuge is

²⁰ 2009. Monitoring Deer Effects on Forest Ecosystems in Pennsylvania State Forests. Research peer review and recommendations for the Pennsylvania Department of Conservation and Natural Resources, Bureau of Forestry, Roger Earl Latham, ed.

²¹ Interim Technical Guidance on Defining Meaningful Desired Conditions for Natural Resources, National Park Service Version 1.0 January 2009.

part of a Superfund site, there are regulations and stakeholders involved not common to all conservation projects. The LGNC is a small non-profit organization that depends heavily on volunteers, so there are limitations in terms of resources including money, time and people. The mission and vision of the LGNC have been recently reviewed by the Board of Directors; the mission components of conservation, education, research and recreation also have to be balanced.

With respect to the grassland, a range of scenarios exist in terms of desired future outcomes:

1. Do nothing and let succession take its course. There are many unknowns with this scenario since comparable models of restoration work at these types of sites are limited or nonexistent. In naturally occurring serpentine barrens, sites which have high soil metal levels and could serve as models for the LGWR, the pathways of succession are not as predictable as in other ecosystems and not well studied (Latham, personal communication).
2. Allow forest succession but control the trajectory towards favorable oaks and other species that will not mobilize the metals from the soil.
3. Maintain a grassland habitat by continually resetting succession through prescribed burns, mass grazing, mechanical removal of woody plants, and/or spot treatment with herbicides. This

may or may not be enhanced by the introduction of additional forbs, deer management, and active control of invasive species.

Latham (through personal communication) has recommended that the various stakeholders of the LGNC sit down to discuss their future vision for the Refuge and to reach consensus. He argues that, as of yet, there is no unified vision of how much of each of the various plant communities should be a part of the patchwork of different native vegetation types on the Refuge; what should be measured in order to track progress toward the goals; or what the target values are for those measurements.

The list of stakeholders is diverse so reaching consensus about the future vision may be complicated. The key baseline ecological assessment information is now available and there is a sense of the key ecological attributes of the site. However, the key indicators that Latham mentions to track progress and measure success for the future still need to be identified. The stakeholders in this next phase need to determine what an acceptable range of variation is moving forward. For example, invasive plant species cannot be completely eliminated, so which should be the main targets of control efforts and monitoring? Some of the early pioneering plants of succession take up the metals, so what is an acceptable risk? Should researchers be worried about food web members of the Refuge developing resistance to high levels of metals? Should diversity indices be used to determine species

richness and evenness at the Refuge? Is this important? If so, do *relevant* indices exist?

The considerations discussed in this conclusion, along with the results of the assessment studies and much discussion and deliberation with LGNC partners and stakeholders, have gone into developing the following list of recommendations for the future.

Moving Forward: Recommendations for the Lehigh Gap Nature Center and Wildlife Refuge

Within its 750 acres, the Lehigh Gap Wildlife Refuge has a number of important and diverse habitats including the grassland that has emerged from a once denuded, metal-contaminated landscape. As noted throughout this assessment, many of the LGNC operations are models from which others can learn: the research collaborations used to complete this assessment; the reliance on a diverse volunteer pool to help carry out the LGNC mission components; and management of disturbed areas ranging from a Superfund site to a utility right of way. The site can also become a model as to how even a relatively small acreage with multiple uses (conservation, revitalization, recreation, and education) can be managed to support multiple users and to utilize ongoing scientific studies to educate students, educators, and the public—without impairing the natural resources.



Despite tremendous progress (restoration and otherwise) at the Refuge in a short amount of time, there is still much to be done and learned. Below is a list of recommendations for moving forward. There are probably other recommendations that the authors of this assessment have not yet thought about and thus, suggestions from others who read this are welcomed and encouraged. The list is not yet prioritized, but will need to be due to the fact that resources, especially in terms of people and finances, are limited and not everything can be done at once. As studies for this assessment were conducted and analyzed, it became clear that many have implications not only for understanding the recovery at the Refuge, but could also be of statewide importance. Hopefully, lessons learned at the LGWR will be used by others.

Inventory Recommendations (filling gaps and adding information)

Extensive surveys of Lehigh Gap Wildlife Refuge now exist for plants (and plant communities), lichens, insects, birds, mammals, and reptiles. However, a number of gaps remain;

additional surveys would help to more fully understand the biodiversity of the Refuge. The LGNC should continue inventory efforts with regard to well-studied taxa, but also focus in the short-term on less well surveyed groups to fill the gaps.

- A more comprehensive survey of amphibians and a survey of fish in the ponds are needed. Amphibians are especially important to monitor because they are highly sensitive to pollution and may be good indicators of metal stress remaining in the ecosystems of Refuge. Amphibians will likely also be sensitive to changes in climate.
- The Lehigh River, which borders the Refuge for more than 2.5 miles, has not been formally included in any survey or ecological research. An ecological assessment of physical, chemical, and biological conditions of the river would complement this assessment. Information from other sources, such as the PA Fish and Boat Commission and the Lehigh River Stocking Association should be identified and reviewed before planning or initiating any inventory project concerning the Lehigh River.
- Certain rare or uncommon vertebrate species might be expected to be found at LGWR because of habitat and geographical location. An effort to locate the following species and/or monitor their numbers is desirable. These species include: Spotted Salamander (*Ambystoma*

maculatum), Eastern Fence Lizard (*Sceloporus undulatus*), Timber Rattlesnake (*Crotalus horridus*), breeding Peregrine Falcon (*Falco peregrinus*), breeding Osprey (*Pandion haliaetus*), breeding Bald Eagle (*Haliaeetus leucocephalus*), and Allegheny Woodrat (*Neotoma magister*). In addition, several vertebrate species, already known to exist at Refuge, are of concern throughout the state and thus, warrant continued monitoring. Included in this list are the Spotted Turtle (*Clemmys guttata*) and River Otter (*Lontra canadensis*).

- A similar effort should be made for plant and invertebrate species of concern such as Wild Bleeding Heart (*Dicentra eximia*), other rare or endangered plants, and rare invertebrates present at the Refuge.



- Two extensive insect surveys have been conducted for the two parts of the ecological assessment for the Refuge. It would be important to have an inventory of other arthropods, including arachnids. In fall 2010, Molly DuVall and Dr. Frank Kuserk initiated a study of microarthropods along the Kittatinny Ridge east of the Lehigh

River. Preliminary results show that there is a drop off in numbers and taxa diversity as one moves closer to the old smelter site (where the metal contamination levels in the soil get higher). It would be beneficial to study and monitor microarthropods along the succession line transects. Clare Kubik, a member of the LGNC Naturalists Club has also begun a survey of spiders (Araneae) at the Refuge. Springtails (Collembola), a lineage of hexapods distinct from insects, have been studied by others in areas contaminated by heavy metals. A review of this literature may provide ideas for future studies of these arthropods at the Refuge.²²

- Forty-two species of Butterflies (Papilionoidea) and Skippers (Hesperioidea) have been identified at the Refuge as of December 2010. However, a formal visual survey of butterflies along transect lines through different seasons has not yet been conducted. This would be of particular interest to do in the grassland area and there have preliminary discussions with

biologists from Fort Indiantown Gap as to how to best conduct such formal surveys.

Monitoring Recommendations

The inventory of species in a given location is not static and this is particularly true in a landscape undergoing recovery where the condition of the habitat is in flux (and hopefully improving). As new plant species emerge or are introduced, the site may contain new food sources and can provide nest sites and cover. These changes can impact which migrating, resident, and breeding species use the Refuge. New species taking advantage of the new habitat can, in turn, impact other aspects of the ecology (herbivory, seed dispersal, etc.). The following monitoring studies will help track such changes.

- *Succession monitoring at Lehigh Gap Wildlife Refuge.* A baseline was established in 2008 with the installation of permanent succession plots and a first year monitoring of trees, shrubs, and total plant cover. Ideally, this monitoring should be conducted annually but it is a time-intensive activity. Recognizing resource limitations, at a minimum, it should be completed every three years.
- *Grassland Enhancement/Deer Plot Monitoring.* The installation of deer exclosures and initial planting of nine native forbs took place in 2009. Monitoring throughout 2009 and 2010 has provided preliminary information on the tolerance of each of these species

²² For instance, see De Bruyn, L., F. Janssens, F. Hendrickx and J-P. Maelfait, Responses of Collembola Communities to Lead Shot Depositions in a Heathland Environment at <http://www.collembola.org/publicat/lead.htm> or Chauvat, M. and J.F. Ponge 2002 Colonization of heavy metal-polluted soils by Collembola: preliminary experiments in compartmented boxes. *Applied Soil Ecol.* 21(2): 91-106.

to the metals and other conditions of the site and resistance to herbivory by deer and other species. This monitoring should continue annually (at least twice each growing season and ideally monthly) until such time as credible results are obtained that can be used in determining which species of forbs to use when doing more widespread enhancement plantings.

- *Herbivory* of the emerging plant species (native and non-native) should be monitored. The enclosure and habitat enhancement studies were designed to allow for this (see Appendix F-2). John Reese, working with Dr. Frank Kuserk of Moravian College, initiated a study of herbivory of a subset of native and invasive plant species in fall 2010 and the results from this study, when completed, may help to guide future, more extensive studies.
- Monitor the results of *forested deer enclosures* at the western end of the Refuge to determine visually the results of fencing on growth of woodland plants (such as spring ephemerals) and tree seedlings of various species.
- Because *woodland edges and shrub habitat* are attractive to some species, the Prairie Warbler Trail area, including the section that borders the state game lands, should be monitored. This area has already been frequented by various sparrows, the prairie warbler, common yellowthroat,

indigo buntings, towhees, cardinals, eastern bluebirds, and tree swallows. It could serve as habitat for blue-winged or golden-winged warbler as well. The same would be true for the savanna habitat on top of the mountain.

- With the call for *climate change monitoring* in Pennsylvania through the work of the 2010 Climate Change Adaptation Working Group on Natural Resources²³, the LGNC should initiate a series of phenological studies. This could include plant emergence: budburst, first (and last) flowering dates, migration events, and emergence of invertebrates (butterflies, bees). This data, used in combination with information from the microclimate weather monitoring stations, could become important baseline information to determine impacts of climate change and any resilience that the ecosystems at the habitat of the Refuge may provide. The Kittatinny Ridge will likely play an important role in climate change adaptation as a migration corridor for a wide range of species – both along the corridor of the ridge *per se* and for altitudinal and south-to-north slope shifts of species seeking cooler environments. Despite this, little to no monitoring of phenology or ecological conditions

²³ See

<http://www.dcnr.state.pa.us/wrcp/climatechange/workgroup.html> and <http://www.dcnr.state.pa.us/wrcp/climatechange/index.html>.

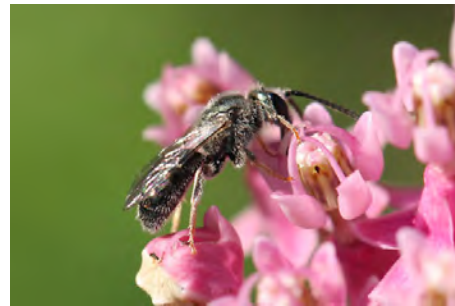
along the ridge has been done. There may be some datasets that could be mined for phenological data such as those that exist for raptor migration (e.g. from Bake Oven Knob and Hawk Mountain). Regional birders may also have important long-term records (field notebooks) that could be analyzed.



Lithurgus chrysurus

Research Recommendations

The above recommendations for further biodiversity inventories and monitoring are research-based and closely linked to the following list of recommendations for further investigations at the LGWR. Some of these studies were initiated during the study period of this assessment and focus on better understanding the emerging and shifting ecological relationships at the Refuge. Such information is needed to guide sound conservation management decisions.



Lassioglossum sp. – The most diverse and most common genus of bees at the LGWR.

- Continue native bee research both as part of the USGS project and to gain a sense of the status of key pollinators at the Refuge. It may also be important to monitor the exotic carpenter bee *Lithurgus chrysurus* populations at the Refuge (and throughout eastern Pennsylvania). Its host plant—spotted knapweed (*Centaurea stoebe*; syn. *C. maculosa*)—is also non-native and common in disturbed areas such as old railway beds including at the Refuge. It is not known if the bee makes use of other plants in Pennsylvania.
- Continue the Monarch (*Danaus plexippus*) tagging project. It is important to monitor which plant species the Monarch uses as a nectar source besides the problematic butterfly bush (*Buddleja davidii*). In addition, this program provides an excellent educational opportunity to increase public awareness about the need for conservation measures on both ends of the migratory route (and stopover sites along the way) for this species.



A Monarch tagging program at LGWR

- Sandwort (*Minuartia patula*) is a unique species at LGWR found only in the zinc-contaminated areas around Palmerton within Pennsylvania.²⁴ A baseline study of its extent in the revegetation zone has been completed by Brockley (see Chapter 8). A continuation of this study will help determine whether it is possible to retain this rare species at the Refuge (this plant species is threatened or endangered in three mid-western states)^{21, 25} or whether new vegetation in the restoration areas will eventually out-compete this plant, especially as the heavy metals become less bio-available.

²⁴ Rhoads, A.F. and T.A. Block 2007 The Plants of Pennsylvania, 2nd ed., Univ. of Pennsylvania Press and USDA Plants Profile <http://plants.usda.gov/java/profile?symbol=MIPA6>; accessed January 9, 2011.

²⁵ 2003 Conservation Assessment for Pitchers Stitchwort (*Minuartia patula*) (*Michx.*) *Mattf.* USDA Forest Service, Eastern Region available at <http://www.fs.fed.us/r9/wildlife/tes/ca-overview/docs/Plants/PitchersStitchwort2003.pdf>.



Sandwort (*Minuartia patula*)

- Eastern Hemlocks (*Tsuga canadensis*) are common at LGWR and are infected with Hemlock Woolly Adelgid (*Adelgus tsugae*). In other nearby areas, hemlocks infected with the adelgid are dying, but Lehigh Gap hemlocks are surviving. An investigation of the reason for this survival is warranted. Two hypotheses are: 1) metal uptake by the hemlocks is imparting some protection from the adelgids; and 2) these hemlocks are on an east facing slope exposed to more sunlight than most hemlocks in the region, which tend to grow in shaded ravines.
- Native forbs are being introduced into the grassland reclamation area. Metal uptake studies and risk assessments regarding these species with regard to pollinators, herbivores, and higher trophic level consumers would provide confidence that metals are not being mobilized into the food chain to the detriment of these other species. Similar studies

should be done on volunteer species that are showing up on Refuge property. Such studies require technical expertise and access to analytical laboratory equipment; funding would be needed for such research.

- Periodically (every three to five years), repeat the bird survey done by C. Husic. Birds are important indicators of habitat quality and changes. Although not included in this assessment, Husic's dataset included detailed information by transect on dates and numbers of species observed. Thus, this can be used as a baseline (correlated with the start of the restoration work) to determine changes in frequency of observation and for phenology studies.
- An analysis of existing diversity indices should be undertaken to see if any are relevant for use with the existing datasets for the LGWR. Such indices can be used to determine species richness and evenness and provide a benchmark as to the success of habitat enhancement to date at the Refuge.
- Work with the PA Department of Conservation and Natural Resources, PA Audubon, the Pennsylvania Natural Heritage Program and other agencies and organizations to coordinate efforts in monitoring of species that are on various watchlists, species that might be particularly vulnerable to climate change, and/or are historically important to Pennsylvania.

- The research collaborations utilized for this assessment and other research projects at the Refuge should be formalized with more regular meetings and enhanced communication on the status of ongoing projects. The work that has been completed and the establishment of a formal collaborative network could be leveraged to seek external funding at the national level.



- Ideally, an ecological field station could be built at the Refuge for scientists and for faculty and students to come to the site to both study what has been accomplished and contribute to ongoing research.
- It would be beneficial to hire someone who can read Old German script to go through the archival records at the Moravian Archives to garner information on the natural history of the Lehigh Gap in the 1740s to help complete the historical record and to compare contemporary conditions.

Management Recommendations

The LGNC is at the point where it needs to not only take stock of the accomplishments of the organization and the success of the restoration work, but to determine the next set of short- and long-term goals. The LGNC should meet with various stakeholders, including EPA representatives, after there has been a sufficient opportunity to review this ecological assessment. It would be wise to establish a task force that includes a wide variety of representatives, including perhaps some outside restoration and conservation experts to help determine the next steps and, more importantly, go through a formal desired future condition analysis. This is important for articulating a complete adaptive management plan.

The Society for Ecological Restoration International (SER) ²⁶ does not directly engage in restoration projects but rather, promotes

“...ecological restoration as a means of sustaining the diversity of life on Earth and reestablishing an ecologically healthy relationship between nature and culture.”

This mission seems to align well with that of the LGNC, and the organization should become more closely involved with SER. This would connect the researchers with a worldwide network of individuals with expertise in restoration and conservation (both scientists and practitioners) that could

be valuable resources for future work at the Refuge.

In the meantime, there are a number of specific management recommendations for the LGNC to consider.

- Continue maintenance of habitat gardens around the Osprey House as demonstration areas, pollinator gardens, and educational areas.
- Continue maintenance and enhancement of the scrub habitat along the power line right-of-way adjacent to the Osprey House.
- Continue efforts to maintain Osprey House pond as an educational asset. Maintain water levels and introduce or remove species as needed to create a healthy, native Eastern Pennsylvania pond ecosystem.
- Inspect revegetation area and steep slopes annually to detect erosion prone areas or areas where re-vegetation has failed or lagged and implement erosion control and revegetation measures promptly.
- A management decision concerning the desired trajectory of succession of the grassland reclamation area should be made by the LGNC Board of Directors. That decision should then be followed with a management plan to achieve the desired outcomes. Options for trajectories include: 1) prairie (native grasses and forbs); 2) savanna (native grasses and forbs with scattered scrub oak,

²⁶ <http://www.ser.org/>

pitch pine, and other fire tolerant species); or 3) allow succession to forest with emphasis on oaks.

- If the above decision is to maintain significant grassland or savanna habitat, consider working with Fort Indiantown Gap biologists to create proper habitat conditions and attempt introduction of Regal Fritillary (*Speyeria idalia*) butterflies to the site.



Buddleja davidii

- Evaluate the results of woodland browsing by deer and take action if necessary to manage numbers of White-tailed Deer (*Odocoileus virginianus*). (See Assessment, Part I.)
- An invasive species management plan has been developed by Arcadis for CBS Operations to control invasive plant species on the revegetated grassland areas of LGWR. This plan includes monitoring and adaptive management to meet the challenges of invasive plant species in the grassland reclamation area. This plan should be expanded to include the entire Refuge, especially the Lehigh River floodplain and Three Ponds areas. (List of invasive species appears in Assessment Part I).
- American Chestnut (*Castanea dentata*) is found on the Refuge and adjacent lands, often reaching reproduction maturity before succumbing to chestnut blight. Its historical presence at Lehigh Gap (Rehn 1903) is reason to consider reintroduction of blight-resistant seedlings as they become available in the near future. These seedlings could be planted where trees already exist in the revegetation area, or in forested exclosures.
- Create a limestone barrens ecosystem along the D&L Trail (paved with limestone) as a model of this type of ecological community.
- Work with the PA Game Commission and National Park Service to develop a grassland management plan for the Pitch Pine/Hairgrass savanna along the southern boundary of the LGWR near the ridge top. Alternatively, explore the possibility of a land swap with the National Park Service and the PA Game Commission to acquire ownership of parcels adjacent to LGWR that

include the Pitch Pine/Hairgrass savanna and un-vegetated areas.

- Monitor the impact of human use on the Refuge in terms of damage to plant species (outside of the trail areas) or introduction of alien species.
- Continue education programs related to conservation and stewardship of the Refuge. Expand citizen science programs including phenology studies.
- Any new graffiti found on LGWR should be removed or covered as quickly as possible. If possible,
- northern border. Critical properties for acquisition include:
 - Trail's End property (and cabin) next to Kingfisher Pond, Mallard Pond, and wetlands;
 - Hauser Tract, adjacent to the entire western border of the property above the LNE Rail bed and PA Turnpike; and
 - Junk yard property and homes along Joseph Lane in Three Ponds area.
- Other properties that would be desirable for operational reasons but are less important ecologically include the Strohl property on the southeast border (next to the Osprey House) and several properties in "Guy's Vacationland" along the LNE Trail at the western end of the property near the Three Ponds.

remove any graffiti with environmentally safe techniques. If no acceptable environmentally safe technique can be found to be effective, cover particularly obvious or offensive graffiti with paint colors that match the rocks.

Land Acquisition

- Much of the land surrounding LGWR is in public ownership, with the National Park Service and Pennsylvania Game Commission owning adjacent properties on the entire southern border of the property and the Lehigh River and D&L Trail adjacent to the entire
- Consider the pros and cons of accepting a donation of "Ecoloam site" on eastern side of Lehigh Gap from CBS Operations.

In all of the future efforts of the LNGC, it will be important to have meaningful community involvement that includes volunteers; researchers, including citizen scientists; recreational users of the Refuge; classes and teachers who use the Refuge as an outdoor laboratory; and those impacted by the restoration work to the Superfund site. The revitalization of the site has not only decreased environmental and health risks, but also turned an eyesore into an attractive and valuable landscape. What has transpired at the Lehigh Gap has become not just another chapter in the region's history, but a story of hope and healing.