

**Lehigh Gap
Wildlife Refuge**

**Ecological
Assessment II**



MORAVIAN
COLLEGE

December 2010

*We gratefully acknowledge funding for
this project from the following sources*

**The Wild Resource Conservation Program of the
Pennsylvania Department of Conservation and Natural
Resources**

Wildlife Information Center (Lehigh Gap Nature Center)

Audubon *TogetherGreen* Innovation Grant and Fellows Programs

CBS Operations

Preferred citation: Husic, D.W¹, C. Husic², D. Kunkle³, and F. Kuserk⁴.
2010. Lehigh Gap Wildlife Refuge Ecological Assessment Part II. Lehigh Gap
Nature Center, Slatington, PA.

¹ ***Primary Author.*** Chair, Department of Biological Sciences, Moravian College, Bethlehem, PA 18018; Correspondence to: dhusic@moravian.edu.

² ***Contributing Author.*** Lehigh Gap Nature Center, P.O. Box 198, Slatington, PA 18080-0198.

³ ***Contributing Author.*** Executive Director, Lehigh Gap Nature Center, P.O. Box 198, Slatington, PA 18080-0198; Correspondence to: danlgnc@ptd.net.

⁴ ***Contributing Author.*** Department of Biological Sciences, Moravian College, Bethlehem, PA 18018.

We are grateful to those who have gathered data, provided information and advice, written or reviewed sections of this report or in some way participated in the studies and projects that are a part of this assessment:

From **Moravian College** (Department of Biological Sciences and the Environmental Studies and Science Program): Drs. Diane Husic and Frank Kuserk
Students: Sarabeth Brockley, John Corbin, Vivian Clarke-Ruiz, Yi Li, Andrew F. Mashintonio, Gregory Niehoff, Nicole Sarson, John Reese, Armando Villafaña, Jr., Meredith Wright and members of the Conservation Biology, Ecology and Microbiology classes.

From the **Lehigh Gap Nature Center**: Dan Kunkle, Maria Tranguch, Bill Mineo;
LGNC Interns: Corey Husic, Sarabeth Brockley, Kyle Janny, Mike and Jenny Bet, Jared Green, and Remy Schneider; and members of the Naturalist Club:
Sean Bankos, Brandon Everett, Corey and Joren Husic, and Clare Kubik.

From **Lehigh University** (Lehigh Earth Observatory or LEO and the Department of Earth and Environmental Sciences): Drs. Bruce Hargreaves, Steve Peters, and Dork Sahagian;
Mr. George Yasko (Field Projects Lab Manager) and Andrea J. Harmer (Director of Web-based Education);
graduate assistants Johanna M.T. Blake and Jill E. Burrows; intern Guthrie Mitchell; and
members of the Civil and Environmental Engineering and Geographic Analysis courses.

From the **Carnegie Museum of Natural History**: Dr. John Rawlins

From **Wilkes University** (Institute for Environmental Science and Sustainability and the Department of Biology): Drs. Ned Fetcher, Ken Klemow, and Michael Steele
Students: Jeff Stratford, George Haleem, and Rachel Curtis

From **West Virginia University** (Departments of Biology and Geology and Geography):
Drs. Jonathan R. Cumming and Dorothy J. Vesper
Graduate Students: Ernest W. Smith and Christian Figueroa-Tyler

From **University of Pennsylvania** (Department of Biology): Brenda B. Casper, Ph.D.
Graduate Students: Sydney I. Glassman and Jennifer Doherty
High School Student Researchers: Julia Leinhauser, Sherilin Joe, and Khalia Thompson

From **Lafayette College**: H. David Husic, Ph.D.

From **Fort Indiantown Gap**: Shannon Henry, Joseph Hovis, David McNaughton, Mark Swartz, and Virginia Tilden,

Jennifer Lansing and staff from **Arcadis BBL**

Roger Latham of **Continental Conservation**

Dr. Hank Edenborn from the **U.S. Department of Energy** (Pittsburgh, PA)

Sue Tantsits and Louise Schaeffer of **Edge of the Woods Native Plant Nursery**

John Dickerson of **Finger Lakes Conservation Services**

Anita Collins, Coordinator for Northeast Pennsylvania Native Bee Project

Sam Droege of the Patuxent Wildlife Research Center,
U.S. Geological Survey

Brian Byrnes of **Pennsylvania Audubon**

Everett Warren of **Green Man Envirosaping**

Lehigh Valley Audubon Society

Charlie Root, **Environmental Protection Agency**

Jim Kunkle, **PA Department of Environmental Protection**

Dave Henry, Forester, **PA Game Commission**

Ken Beard, **PA Department of Environmental Protection**

Jim Frank, Environmental Engineer, **Frank & West, Inc.**

Abel Boyer and Family

Photo credits: Corey Husic, Diane Husic, H. David Husic, Dan Kunkle, Sarabeth Brockley, Frank Kuserk, Vivian Clarke-Ruiz, Todd Johnson, and Roger Latham

List of Abbreviations used in Report

2,4-D – 2,4-Dichlorophenoxyacetic acid (an herbicide)

AMF – Arbuscular Mycorrhizal Fungi

Cd – Cadmium

CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act of 1980

CLPP – Community-level Physiological Profiling

Cu – Copper

D&L – Delaware and Lehigh (Trail; part of the D&L National Heritage Corridor)

DCNR – Pennsylvania Department of Conservation and Natural Resources

EPA – the U.S. Environmental Protection Agency

FIG – Fort Indiantown Gap

GPS – Geological positioning system

IR - Infrared

kg – kilogram

LEO – Lehigh Earth Observatory (at Lehigh University)

LGNC – Lehigh Gap Nature Center

LGWR – Lehigh Gap Wildlife Refuge (the “Refuge”)

LNE – Lehigh and New England (Trail; part of the historic rail bed)

mg – milligram

OU1 – Operable Unit 1 (refers to a part of the Superfund site)

Pb – Lead

ROD – Record of Decision

ROW – Right-of-way

SER – Society for Ecological Restoration International

SLIPP – Service Learning in Public Policy (a program for high school students out of Valley Forge)

SOAR – Student Opportunities for Academic Research (a program at Moravian College)

SWRAU – Sitewide Ready for Anticipated Use (regarding Superfund sites; an EPA term)

USGS – United States Geological Survey

WIC – Wildlife Information Center

WNS – White-nose syndrome (in bats)

WRCP – Wild Resource Conservation Program

Zn – zinc

Table of Contents

Front matter and Acknowledgments

Preface and Executive Summary..... p. i - iv

Section I

Chapter 1. Introduction..... p. 1-1 to 1-5
Chapter 2. Methodology..... p. 2-1 to 2-3

Section II –Biota of the Lehigh Gap Wildlife Refuge

Chapter 3. Mammals p. 3-1 to 3-10
Chapter 4. Reptiles and Amphibians..... p. 4-1 to 4-6
Chapter 5. Birds..... p. 5-1 to 5-18
Chapter 6. Insects..... p. 6-1 to 6-19
Chapter 7. Microorganisms p. 7-1 to 7-6
Chapter 8. Plants..... p. 8-1 to 8-28

Section III – Ecological Studies, Abiotic Parameters, and Risk Assessment

Chapter 9. Ecological Studies..... p. 9-1 to 9-20
Chapter 10. The Physical Environment and Risk Assessment..... p. 10-1 to 10-12
Chapter 11. Mitigating Hazards and Addressing Previous
Recommendations from the LGWR Ecological
Assessment – Part I..... p. 11-1 to 11-8

Section IV – Conclusions and Recommendations

Chapter 12. Conclusions: Reflections and Recommendations..... p. 12-1 to 12-22

Section V. Appendices

- A. List of researchers, consultants, and collaborating partners
- B. Vertebrates of the Lehigh Gap Wildlife Refuge
- C. Insect Data
 - C-1: Preliminary Faunal Assessment for Insects, Part II, John E. Rawlins, Carnegie Museum of Natural History (6/29/10)
 - C-2: “Tips on How to Use Bee Bowls to Collect Bees” by Sam Droege
 - C-3: Preliminary List of Bee Species Identified in LGWR Study
 - C-4: Species list for Lepidopterans and Odonatans at the LGWR

- C-5: Compilation of Insect Species at the LGWR
- D. Macroinvertebrate Diversity in Metal Contaminated Ponds of the Lehigh Gap Refuge
- E. Microorganisms
 - E-1: Current State of the Soil Microflora at the Palmerton, Pa Superfund Site
 - E-2: Evidence for Zinc Tolerance among Bacteria of the Palmerton, Pa Area
 - E-3: Poster: Clarke-Ruiz and Kuserk Bacterial Zinc Tolerance Study
 - E-4: Poster: Sarson and Kuserk Bacterial Identification Study
 - E-5: Abstract: Casper Laboratory Studies on Arbuscular Mycorrhizal Fungi
- F. Habitat Enhancement
 - F-1: Lehigh Gap Wildlife Refuge Native Habitat Garden Database
 - F-2: Experimental Design – Grassland Enhancement/Deer Fencing Project Report
 - F-2a: Summary of 2009 Plant Monitoring Data
 - F-3: Acorn and Seedling Planting – Field Trials
- G. Moravian College Plant Studies (Research Poster)
- H. Ecological Studies
 - H-1: Succession Monitoring Report
 - H-1a: August 2008 Succession Plot Monitoring Data
 - H-1b: 2008 Cumulative Succession Data
 - H-2: 2008 Educational Succession Plot Plant Inventory
 - H-3: Total Vegetative Cover Analysis Educational Activity
- I. Wilkes Food Web Study
- J. Educational Habitat Displays
 - J-1: Forest
 - J-2: Grassland
 - J-3: Ponds
 - J-4: River/Riparian
 - J-5: Scrub
 - J-6: Wetland
- K. Lehigh University Research Studies
 - K-1: Lehigh Research Technical Report (December 2010)
 - K-2: Lehigh Metals Studies Pamphlet
 - K-3: Lehigh Metals Research Poster

Preface

In 2006, Natural Lands Trust, Continental Conservation, and Botanical Inventory completed the first phase of ecological assessment of Lehigh Gap Wildlife Refuge (LGWR) for the Wildlife Information Center, now known as Lehigh Gap Nature Center (LGNC). This assessment concentrated on plants and plant communities and also included light-trapped insects and lichens. While a valuable tool and partial baseline study of the Refuge, many more taxa and conditions remained to be studied to develop a more complete baseline assessment for use in management of habitats and biodiversity on the Refuge and to inform decisions regarding educational, research and recreational programs and activities on the refuge.

In 2007, LGNC succeeded in obtaining grant funding from the Wild Resource Conservation Program to continue the assessment process to fill in the gaps remaining in the first assessment. Additional funding from several other sources complemented the WRCP funding to help complete the assessment. In addition, vast numbers of volunteer, internship, and academic partner hours were contributed to complete the studies in this assessment. Our academic partnerships made the work possible.

This assessment covers a broad range of physical and biotic factors, establishes a baseline for ongoing monitoring, and resulted in a network of academic and agency partners that can continue research at the Refuge. It is also a very important study because of its location on the Kittatinny Ridge, which is of statewide

and regional importance ecologically, especially in a world with a changing climate.

With regard to the ecological community, Aldo Leopold wrote¹ “To keep every cog and wheel is the first rule of intelligent tinkering.” It is difficult to manage an ecosystem if you don’t know what its components and interactions are. We now know many of the “cogs and wheels” of the ecosystems and communities of Lehigh Gap Wildlife Refuge, and have a pretty good idea of some that are missing from the system as well. This assessment will help us be intelligent tinkerers.

DK

A note about names. The Wildlife Information Center, Inc. is the official IRS and PA Charities Bureau name of the 501(c)(3) nonprofit organization that purchased the land that became known as Lehigh Gap Wildlife Refuge, a privately owned 750-acre reserve on the Kittatinny Ridge at Lehigh Gap. After operating the Refuge and its successful ecological reclamation program, the Wildlife Information Center registered to officially do business as Lehigh Gap Nature Center. Thus, the organization that operates the Lehigh Gap Wildlife Refuge (the land) is the Lehigh Gap Nature Center (the organization).

¹ Leopold, Aldo. 1949. *A Sand County Almanac, With Essays on Conservation from Round River*. Oxford University Press, London.

Executive Summary

Over the past six years, the Lehigh Gap Nature Center (LGNC) have undertaken the task of producing a comprehensive ecological assessment of Lehigh Gap Wildlife Refuge (LGWR) because part of the Refuge is encompassed by the Palmerton Superfund site, and also because it is on the ecologically important Kittatinny Ridge. The first phase of the assessment was published in 2007 and has led to significant progress (see Chapter 11) in addressing the resource challenges and threats outlined in the document.

Upon completion of the first phase of the ecological assessment, the LGNC procured funding for a phase two of the assessment, with the objectives of: 1) filling in gaps from the first assessment with regard to the baseline ecological conditions of LGWR, 2) gathering information about the ecological interactions occurring in both the restoration area and other habitats of the Refuge, and 3) using the information obtained to develop monitoring protocols to allow adaptive management of the resources at LGWR.

In this phase of the assessment, the following studies and inventories were performed, greatly enhancing our understanding of the biota, physical conditions, and ecological interactions of the refuge:

- Inventories of mammals (Ch. 3); reptiles and amphibians (Ch. 4); birds (Ch. 5); flying, crawling, and aquatic insects, including special surveys of bees, butterflies, odonates, and aquatic macroinvertebrates (Ch. 6); and soil microorganisms (Ch. 7). We also added to the inventory of plants from Part I of the assessment (Ch. 8), and are working on a bioacoustics survey of the Refuge (Ch. 9).
 - Ecological studies (Ch. 9) of:
 - Succession in the grassland revegetation area and of the Prairie Warbler Trail scrub habitat
 - Total plant cover in the revegetation zone
 - Metal uptake and risk assessment in the remediation area
 - Food web and herbivory in the grassland area
 - Habitat changes and disturbances throughout the refuge
 - Studies of the physical conditions of the Refuge (Ch. 10) including:
 - Soil metal levels
 - Ground and surface water metal levels
 - Microclimate
- As of December 2010, 23 species of mammals have been observed at the Refuge. The Carnegie Museum of Natural History has range distribution maps for each county in Pennsylvania. From their records, a total of 51 species have been documented in Carbon and Lehigh Counties combined. Thus, over 40% of these have been observed at the LGWR.

Interestingly, porcupines have been documented at the Refuge but are not noted in the Carnegie Museum's range maps for this area of the state.

Over 50% of the species of reptiles and amphibians ("herps") documented for Carbon and Lehigh Counties by the Pennsylvania Herpetological Society have been observed at the Refuge. To date, 164 bird species have been reported, and since the establishment of the grasslands, new species are not only seen at the Refuge, but are breeding at the site.

Extensive insect surveys have been conducted at the Refuge (for both Part I and II of the ecological assessment) and, to date, the compiled total of species is 851. Many of the insect surveys and research projects have significant educational components for the public and many of the findings have relevance beyond the LGWR.

Current studies of soil microbes (bacteria and mycorrhizal fungi) show recovery from previous reports from the 1970's. These organisms are important for soil quality, decomposition of organic matter, and plant growth since some of them play roles in nutrient availability and uptake and can help to confer metal tolerance.

The LGNC has continued to monitor invasive plant species as well as early successional plants. Some of these take up the metal contaminants from the soil, presenting new management questions for the site. Significant progress has been made in terms of habitat enhancement and the native plant/habitat gardens are important educational tools at the Refuge.

A number of abiotic conditions (physical parameters) have been studied including the distribution and persistence of the metal contaminants in the soil, seeps and springs at the LGWR. Weather stations have been installed to allow a number of future studies, including analysis of microclimates at the Refuge and long-term climate change monitoring.

Chapter 11 summarizes the way in which hazards identified in Part I of the assessment have been addressed. The LGNC has worked on the majority of the recommendations from Part I of the assessment and this progress is also summarized in Chapter 11. Finally, based on the findings of the two phases of the assessment and the work done as a result of the recommendations of the first phase, a new set of recommendations has been formulated and put forth in the conclusion of this phase of the assessment (Ch. 12). The major recommendations of the report include:

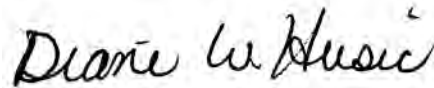
- Maintain up-to-date species inventories and fill in gaps for taxa not surveyed.
- Continue monitoring efforts of succession, grassland enhancement, herbivory, and impacts of climate change.
- Maintain the network of researchers, including professional and citizen scientists to continue the valuable research occurring at LGNC and initiate new studies as warranted by monitoring and evaluation.
- Determine the desired trajectory of succession in the grassland revegetation area and manage accordingly.

- Continue managing the Refuge with protection of resources as highest priority but allowing research, educational, and recreational uses which do not degrade the resources.
- Acquire additional appropriate land parcels as funding permits to protect the resources of the Refuge and enhance other uses.

While no ecological assessment can be totally complete, the broad range of taxa studied, the wide range of physical factors studied, and the ecological interactions investigated in the two phases of this assessment give the LGNC an excellent picture of the ecology, physical environment, and organisms present at LGWR at this time. It will serve us well in the future to inform management decisions and set the parameters for future research.



Dan Kunkle, Executive Director, Lehigh Gap Nature Center



Diane W. Husic, Chair, Department of Biological Sciences, Moravian College

Section I

Introduction (Background) and Methodology for the Ecological Assessment – Part II

Chapter 1

Introduction



Introduction

LGNC history and mission

The Wildlife Information Center (WIC) was founded in 1986, primarily as a research and advocacy organization. In 1998, a leadership change and a subsequent strategic planning process, funded by the William Penn Foundation, resulted in a re-defined mission with an emphasis on conservation, education, and research for the sake of wildlife and people. Capacity building and development of the Board of Directors became high priorities, and acquisition of land for a community nature and environmental education center became a major emphasis. The Board members' dream of owning land became a reality when they launched a bold initiative to purchase over 750 acres of land on the Kittatinny Ridge (Blue Mountain) in eastern Pennsylvania.



The Lehigh Gap

With the acquisition of land at Lehigh Gap, the Center's work became focused geographically at that location, prompting the Board of Directors to register the name "Lehigh Gap Nature Center" (LGNC) as an official name by which the organization can do business.

The land has been set aside as a wildlife refuge and is referred to as the Lehigh Gap Wildlife Refuge (LGWR or the Refuge).

The images on the following pages include 1) a panoramic photograph of the LGWR property along the north face of the Kittatinny Ridge stretching from the Lehigh Gap to the Northeast Extension of the PA Turnpike (Interstate 476); 2) a GoogleEarth® image of the property; and 3) a map of the property parcel prepared for the 2007 Lehigh Gap Wildlife Refuge Ecological Assessment (Part I) by the Natural Lands Trust.¹



Location of the Lehigh Gap Wildlife Refuge (Map generated for the 2007 Ecological Assessment by the Natural Lands Trust.)

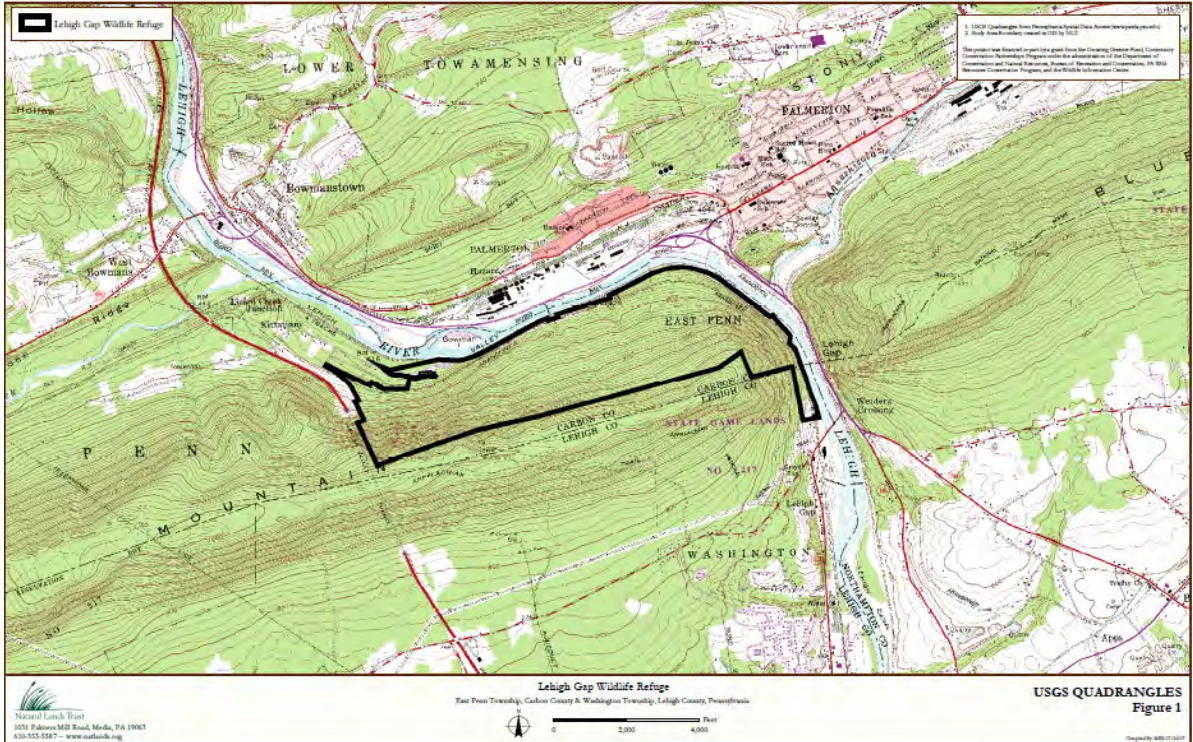
¹ Available at <http://lgnc.org/wp/wp-content/uploads/2009/06/lgnc-ecological-assessment.pdf>.



A view of the LGWR property (the north face of the Kittatinny Ridge)



A GoogleEarth® image of the LGWR property showing the Lehigh River to the east and north of the property.



The LGWR property parcel outlined in black

What makes this particular land acquisition and story unusual is that some of the acquired property was badly damaged by air pollution from zinc smelter plants in the area that had operated between 1898 and 1980. The mountainside was largely devoid of vegetation, the topsoil had eroded away, the ground was highly contaminated with heavy metals (zinc, lead, cadmium and arsenic), and, as such, the area couldn't support other forms of wildlife. In fact, about one half of the property is on the National Priorities List as part of the Palmerton Superfund Site and, at the time of purchase, was in need of complete ecological restoration. Thus, LGNC became involved with the U.S. Environmental Protection Agency (EPA) program ongoing at the site. Upon advice of some consultants and friends

of the LGNC, attempts to re-vegetate the site using with native (mostly warm-season) grasses began in 2003. The grasses are tolerant of heavy metals in the soil, do not significantly take up the metals, have deep root systems to help reduce erosion and can gradually build topsoil. Details of this reseeded and re-vegetation process have been described elsewhere.²

Using innovative restoration methods, a functioning ecosystem has been restored on the barren landscape in less than 5 years. Valuable grassland habitat is being established on nearly 400 acres of mountainside that was devoid of vegetation for half a century.

² For instance, see the series of articles at <http://lgnc.org/conservation>.



A portion of the LGWR property in 2003 prior to seeding with native grasses in the original test plot areas. Notice the severe erosion along the former LNE rail bed.



The same area of the LGWR property in 2008 after the seeding process.

In addition to the restoration area, there are a variety of other healthy habitats on the Refuge. These include a 2.5-mile riparian zone along the Lehigh River, forested slopes, vernal pools and other wetlands, ponds, seeps and springs, hemlocks, and a pitch pine/hairgrass savanna of statewide significance (R. Latham, personal communication, 2005) along the top of the Kittatinny near Lehigh Gap³. The property has been established as a

³ See also 2007 LGWR Ecological Assessment -- Part I; available at <http://lgnc.org/wp/wp-content/uploads/2009/06/lgnc-ecological-assessment.pdf>.

wildlife refuge, open to the public for passive recreation and educational opportunities.

The demonstrated ability to both return functioning ecosystems to the formerly barren area and use the project as the focal point of a wide range of education efforts propelled the Center into yet a new era. A capital campaign was launched to raise funds for infrastructure and facilities improvements that will enhance the capabilities of the LGNC with regard to education programming, visitor services, and passive recreation at the nature center. Groundbreaking for a new visitor and education center took place July 24, 2009 and the building was officially opened to the public on July 16, 2010.



The new LGNC visitor and education center

Education is Central in the LGNC Mission. The Lehigh Gap Environmental Education Partnership was initiated in late 2004, in which the LGNC works with the local school districts to develop K-12 curriculum involving the LGNC staff and volunteers and use of the Refuge. The key objective is to deliver environmental education to students in a way that is meaningful and consistent throughout the students' K-12 career. It is expected that this program will result in high achievement on the Environment and Ecology portion of the Pennsylvania System of Student Assessment tests, and preparedness for life beyond school. Over 2,000 students were served during the past year in the education programs.



Besides K-12 educational opportunities, students from nine different colleges participated in class trips, presentations, or research opportunities at the LGWR property. Over the past six years, LGNC has provided paid internships in ecology and wildlife research for 18 students providing unique real world learning experiences that illustrate the intersections between science and policy in this revitalization project.

Academic research partners at Moravian College, Lehigh Carbon

Community College, Kutztown University, Lehigh University, and the University of Pennsylvania have already incorporated Lehigh Gap Wildlife Refuge into their curriculum as a case study, field laboratory activity, or research opportunity. A future goal is to develop an ecological field station at the site in collaboration with our network of researchers and academic institutions.



In addition to programs for students, a strong program of teacher workshops has been developed in to help train teachers in ecology and environmental issues. Elementary and middle school teachers are now responsible for teaching these subjects in Pennsylvania, with their students accountable on state tests. These workshops have been developed and are taught in conjunction

with Moravian College, where the teachers can opt for academic credit for the courses in addition to gaining Act 48 continuing education credit through the Pennsylvania Department of Education.



The Lehigh Gap Environmental Education Partnership is just one part of a highly regarded environmental education program. The LGNC has been approved as an Educational Improvement Organization by the Commonwealth of Pennsylvania, and, as such, qualifies for business donations that can be used in the Education Improvement Tax Credits program. The educational programs include: Young Ecologists Summer Camp, Wonderful World of Wildlife reading program, Lehigh Gap Naturalists Club, field trips, programs in classrooms, an internship program, adult and family-oriented public programs and workshops, and teacher training.



The Lehigh Gap Naturalists Club



The members of the Naturalist Club are participating in two national projects: a) Monarch Watch butterfly migration tracking program⁴ through the University of Kansas and b) a native bee survey with the U.S. Geological Survey and the Smithsonian Institution. The club was recently featured in Audubon magazine, a national publication.⁵



⁴ See <http://www.monarchwatch.org/>.

⁵ See

<http://audubonmagazine.org/citizenScience/citizenscience0905.html>).

An important aspect of the public education component of the LGNC mission is to honor the importance of the history of the region. The value of the industries that built the region and were the foundation of the Industrial Revolution in the United States is recognized – despite the environmental damage that may have resulted from the industrial processes. This philosophy is consistent with the opinions expressed by Daniel Bluestone in a chapter entitled “Toxic Sites as Places of Culture and Memory: Adaptive Management for Citizenship” from a book published after the 25th anniversary of the Superfund legislation. He notes the need to both “engage industrial sites historically” and “cultivate a politics of place to encourage site stewardship”.⁶ So rather than covering up the history along with the contaminants, the historical significance should be landmarked and celebrated as new stories of ecological resilience and the value of the new uses (such as recreation) at the once contaminated site are told.



A second emphasis is research. Research, of course, overlaps with education and has become a prominent part of the LGNC program. More than 70 researchers – including high school students, college undergraduates, Ph.D. students, academic professionals, and government scientists – have been

⁶ Macey, G.P. and J.Z. Cannon, 2007. Reclaiming the Land: Rethinking Superfund Institutions, Methods and Practices. Springer Press.

involved with some kind of research work at LGWR. To date, two roundtables have been convened to strengthen this research network and explore potential collaborations. The last roundtable in May 2009 was attended by 40 people. Many of these individuals contributed to the work reported on in this assessment.

The most significant research partnerships have been with Moravian College and Lehigh University. The LGNC has hosted 10 undergraduate research students from Moravian under the guidance of Professors Diane Husic and Frank Kuserk. Both of these professors also utilize the site for field studies for a variety of classes and Husic co-taught a conservation biology class with LGNC director Dan Kunkle based, in part, on the conservation and restoration work at Lehigh Gap. Another half dozen graduate and undergraduate interns from Lehigh University have done research work at LGWR and Professor Bruce Hargreaves has set up a microclimate monitoring network that will support future ecological research.



Meredith Wright presenting her research at the State Capitol in Harrisburg



Passive outdoor recreation is a part of the LGNC mission. Along with the rehabilitation work that has been done at the Refuge have come opportunities for enhanced visitor experiences from hiking (the site borders both the D&L Trail and the world famous Appalachian Trail), photography, wildlife watching (the Refuge has excellent habitats for various kinds of birds, amphibians, and turtles), botanical and geological studies, and other low-impact passive recreational pursuits. A number of trails have been created and the LGNC is working on interpretive signage and brochures for these areas that will discuss not only the natural history and resources, but also historical aspects of the site and the types of research projects that are ongoing. In developing maps for this assessment, new trail

maps for the Refuge were also prepared (see above).

The natural values at the LGWR site will increase the quality of life for all the residents of the Lehigh Valley area, and present economic opportunities to local businesses who capitalize on the visitors who need services. Because of the recreational and educational value of the site, and the increasing use of the property, it is important to ensure that the management decisions are based on sound science and information. In short, LGNC intends to practice good stewardship of the resources, enhance habitats where possible, and allow human use without diminishing the ecological value of the Refuge.

A fourth and critical emphasis in the mission of the LGNC is conservation.

Because of the importance of the Refuge from a biodiversity standpoint given the diminishing amount of open space in the eastern United States, especially grassland habitat, it is imperative that the Refuge be managed in an ecologically sound manner. Ideally, the Lehigh Gap Wildlife Refuge will become an exemplary model of protected and well-managed lands along the Kittatinny Ridge. The site is also unique in that it has undergone remarkable transformation from a denuded, highly contaminated site to a grassland habitat which now supports a range of wildlife. The restoration work has gone beyond reducing the environmental and human health risk or allowing the contaminated land to be reused for another industrial site. As such, it is also a model for restoration work at other Superfund and Brownfield sites.



There are not many comparable projects to what has occurred at the LGWR site; thus, the future of how this site will continue to respond is somewhat of an unknown – i.e. it is an experiment-in-progress for restoration work, land management, and conservation. Extensive literature reviews have turned up few clues as to how to manage such a site. Signs of succession, the appearance of invasive

species, and changes in wildlife species that use the site as a stopover or breeding ground are already evident. Thus, the LGNC conservation efforts will, by necessity, include short- and long-term monitoring and adaptive management approaches based on the best information available at a given point in time. Thorough ecological assessments not only provide critical “baseline” information for proper management of the Refuge at this early stage of the restoration process, but also important information about the Kittatinny Ridge, an area of statewide significance as both a valuable natural resource and as part of the state’s largest Important Bird Area.



The Kittatinny is world famous as a leading line for raptor migration, but it is also a major stopover habitat for migrating songbirds, and a dispersal corridor for vertebrates and plants. It provides a number of ecosystem services such as water filtration and groundwater recharge, and the forests along the slopes serve as significant carbon sinks. Audubon Pennsylvania has designated the Kittatinny as an Important Bird Area, and PA Department of Conservation of Natural Resources has designated it as a high priority corridor for land acquisition and conservation. The DCNR also helps

fund the Kittatinny Coalition (of which the nature center is a charter member), whose role it is to advocate and plan for protection of the ridge. In addition, the Lehigh River was designated DCNR's River of the Year in 2007. Thus, this project has not only statewide, but also national and global significance, especially with relation to the migrating songbirds and raptors that are currently in decline.



The Kittatinny Ridge is part of the watershed for both the Delaware and Susquehanna River drainages, and, as such, is important to drinking water and water quality for more than half of Pennsylvania's residents. This project directly affects the water quality of the Lehigh River, and subsequently the people of Lehigh, Northampton and Bucks Counties, and the city of Philadelphia.



Given the risk of contaminant run-off or leaching from the Superfund site, it is important to continually monitor the water quality in 1) the seeps and springs at the Refuge; 2) the section of the Lehigh River that runs adjacent to the Refuge and through the Lehigh Gap; and 3) of ponds on the western end of the property. This is being done by determining metal levels in water samples, evaluating the diversity of aquatic macroinvertebrates, and conducting periodic surveys of biodiversity in and around the river, ponds and wetland areas.



During the period of which this assessment was being conducted, it became clear that future conservation on the Kittatinny Ridge would need to take climate change into consideration. From climate change modeling and impact studies, there is significant evidence that the ridge will 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. The climate change models from the National Oceanic and Atmospheric Administration show that the ridge will likely experience significant warming over the next several decades, although the changes will be less dramatic than regions south of the mountain. According to the Union of Concerned Scientists report entitled *Climate Change Impacts and Solutions for Pennsylvania*, conditions may become unsuitable for many of the important hardwood tree species in Pennsylvania such as black cherry, sugar maple and American Beech.⁷ This, in turn, negatively impacts critical habitat for key resident and migratory bird species. The importance of the Kittatinny Ridge as a corridor for climate migrants and the need for ecological monitoring was noted numerous times during meetings of the PA Climate Change Adaptation Working Group on Natural Resources.⁸ Despite the importance of the ridge in climate change resilience and adaptation, relatively little is being done to monitor phenology along the ridge in Pennsylvania.

~~~~~

This assessment is vital to developing monitoring protocols and to inform

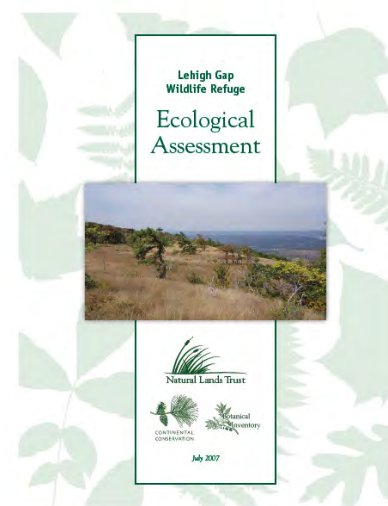
---

<sup>7</sup> 2008. Climate Change Union of Concerned Scientists Report in Pennsylvania: Impacts and Solutions for the Keystone State. [http://www.ucsusa.org/global\\_warming/science\\_and\\_impacts/impacts/climate-change-pa.html](http://www.ucsusa.org/global_warming/science_and_impacts/impacts/climate-change-pa.html).

<sup>8</sup> For information on the PA Climate Change Adaptation working group, see <http://www.dcnr.state.pa.us/conservationscience/climatechange/index.htm>. The complete report on climate change adaptation for PA will be released by DEP in January 2011.

management of this critical and unique site, especially with the rapidly expanding use of the site for recreation and education. These protocols and the restoration project have vast implications for other natural areas and restoration projects throughout the state and beyond. Given that ecological restoration is a relatively new field and there is relatively little in the scientific literature about rehabilitating Superfund sites to wildlife refuges, the restoration work at Lehigh Gap is regarded as a series of scientific experiments, which need to be carefully documented and continually monitored.

## Ecological Assessment – Part I



In 2005, the initial ecological assessment of the LGWR property was undertaken with funding from the Growing Greener Fund, Community Conservation Partnerships Program under the administration of the Pennsylvania Department of Conservation and Natural Resources, Bureau of Recreation and Conservation Pennsylvania Wild Resource Conservation Program, and Wildlife

Information Center. The project was coordinated by the Natural Lands Trust (out of Media, PA) in conjunction with Continental Conservation and Botanical Inventory, along with a number of other specialists and scientists.<sup>9</sup>



The 2005-06 ecological assessment provided detailed information about Lehigh Gap Wildlife Refuge that will prove invaluable in management of the Refuge. This is the description of the assessment as described in the grant proposal:

*The proposal (Steckel 2005) calls for a two-year study, including a total ecological inventory of the entire property in year one, with a second year of intensive study of hotspots identified in the year one inventory. The main goals and objectives of the assessment are to:*

*1) Survey the extant plant communities, their component species (including any animal species*

*of special concern), and current state of health.*

*2) Catalog the current stewardship issues and provide general recommendations designed to protect and enhance native plant communities, facilitate educational opportunities and minimize impacts of proposed recreational uses.*

*The results of the project will include GIS mapping and ecological analysis, with recommendations for management of the refuge. We expect this to become part of our Master Site Plan, the guiding document that will allow us to manage this internationally important resource with the best stewardship possible.*

The assessment succeeded in accomplishing these objectives and exceeded them; during the scope of the project, two other major groups were assessed: light-trapped insects (primarily moths) and lichens. This data provided insight into the ecological health and state of recovery of the restoration zone. Four plants of special concern were found, including perhaps the largest population of wild bleeding heart (*Dicentra eximia*) in the state. Other Pennsylvania endangered or threatened species include two *Carex* sedges, and southern wild senns (*Senna marilandica*).

---

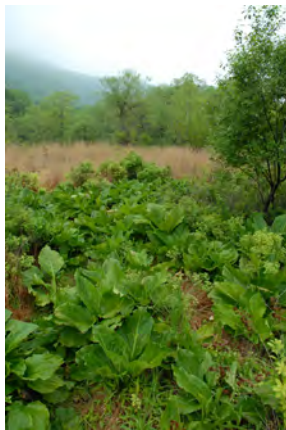
<sup>9</sup> See complete list in Latham, R. E., D. B. Steckel, H. M. Harper, C. Steckel and M. Boatright, 2007. Lehigh Gap Wildlife Refuge Ecological Assessment; available at <http://lgnc.org/wp/wp-content/uploads/2009/06/lgnc-ecological-assessment.pdf>.



*Dicentra eximia*

A grassland/savanna of statewide significance was also discovered on the Refuge and adjoining National Park Service and PA State Game Lands and is likely the largest natural, native grassland in the state, according to ecologist Roger Latham (personal communication, 2005).

The ponds/wetlands/vernal pool complex at the base of the ridge next to the Lehigh River were determined to also be an area of great significance because of its importance to a variety of unique species, including river otters, and two of the endangered plant species.



Of particular importance, Part I of the LGWR Ecological Assessment made a

series of recommendations related to stewardship, educational and recreational opportunities and future research.

## **The Ecological Assessment – Part II**

The primary goals for this second phase of the LGWR Ecological Assessment were:

- To complete the baseline assessment of the LGWR property and biodiversity;
- To establish protocols for ongoing monitoring to inform decision-making and allow adaptive management of the natural resources of the Refuge; and
- To follow-up on stewardship issues and recommendations from the first assessment.

In spite of the value of the Natural Lands Trust assessment report and the fact that it exceeded the objectives for data collection and analysis, the baseline assessment is still incomplete. The NLT report provided excellent baseline information and maps for plant communities, moths, lichens, and physical features of the Refuge. It also included some preliminary data on insect populations (primarily moths). In Part II, information has been gathered on various vertebrates groups (birds, mammals, amphibians and reptiles); native bee and other insect populations; ecological interactions, especially with regard to the restoration area and the uptake and effects of heavy metals by plants; and the physical

environment of the Refuge including microclimate and water quality. A number of studies have been designed and implemented and preliminary data collected; most of these will be longitudinal studies spanning many years.

The monitoring protocols established during these two parts of the assessment studies provide the framework for ongoing ecological monitoring that will continue well into the future. These protocols include establishment of permanent test plots for succession monitoring, studies of herbivore pressure, and habitat enhancement experiments. The biodiversity studies also outline the protocols and schedules for future assessments that will be used for comparisons to the baseline data and inform subsequent management decisions about the resources of the Refuge.

### **Objectives for Phase II of the LGWR Ecological Assessment**

There were three overarching questions that were intended to be addressed in this assessment:

1) ***What is the baseline ecological condition of all the diverse habitats of the Lehigh Gap Wildlife Refuge?*** Baseline data had already been established for plant communities, plant species, night flying insects, and lichens and produced some GIS mapping of plant communities, stewardship features and hazards, and trails. In this assessment, the intention was to assess the status of various

vertebrate and invertebrate animal groups, selected microorganisms, and microclimate, and adding GIS maps to the existing collection.

2) ***What are the ecological interactions that are occurring that impact both the restoration area and other habitats on the Refuge?*** There are numerous questions to be answered concerning invasive species detection and management; the physical environment and of the interactions of plants and metals; and succession and habitat enhancement efforts.

3) ***How can the information learned in the assessment be used to set up monitoring protocols to allow for adaptive management of the Refuge's habitats and to manage the ecological restoration processes in the grassland restoration area of the Refuge?*** These protocols should be designed to be flexible, to ensure protection and enhancement of biodiversity on the Refuge, and to monitor the fate of and risks associated with the contaminants that remain onsite. The revitalization work and adaptive management plans that are developed should be useful as models for rehabilitation and monitoring at other sites as well.

A detailed list of proposed research questions was included in the original proposal to the Wild Resource Conservation Program of the PA DCNR. Most of the things on list have been accomplished and are discussed in this report. The LGNC also took advantage of some opportunities that came along

over the past two years, and as is typically the case in science, some things took longer than expected so are still works in progress or else the projects didn't develop as expected. Furthermore, new questions arose, such as consideration of the impact of climate change on the management efforts at the LGWR site and along the Kittatinny Ridge in general.



## *Chapter 2*

# *Methodology*



# Methodology

## **Approaches used to conduct Part II of the LGWR ecological assessment**

Part II of the ecological assessment provides additional baseline data and sets up protocols for ongoing monitoring and management of the Refuge. To effectively inventory and monitor a recovering habitat and biodiversity, many forms of expertise and types of projects are required. The Lehigh Gap Nature Center is extremely fortunate to have a wide array of scientists, institutions, and research ideas committed to the goals of this proposal and the restoration and protection of a unique site.

This assessment project was made possible through funding from the Wild Resource Conservation Program (WRCP) of the Pennsylvania Department of Conservation and Natural Resources (DCNR). This is Pennsylvania's biodiversity conservation program that supports the study and conservation of rare species and habitats. A Superfund site that has been converted to a grassland and wildlife refuge is indeed a unique habitat! Part I of the ecological assessment (2007) also identified a number of rare plant species for Pennsylvania.

This state funding was leveraged greatly by support from academic institutions, particularly Moravian

College's Student Opportunities for Academic Research (SOAR) student summer research program, Lehigh University's Lehigh Earth Observatory (LEO) and faculty members from Moravian, Lehigh, and several other institutions. Lehigh Gap Nature Center also dedicated significant staff resources to the project. The grant from WRCP, the previous restoration success at the LGWR, and partnerships with Pennsylvania Audubon and the Lehigh Valley Audubon Society made possible a successful proposal to the Audubon *TogetherGreen* Innovation Grant program to help support the deer exclosure and habitat enhancement projects. In 2008, D. Kunkle was awarded an Audubon *TogetherGreen* Fellowship, the money from which was used to support many of the projects conducted by the LGNC Naturalists Club members and an intern that are included in this report.

Our approach for completing the baseline ecological assessment and develop expanded species databases and mapping collections has been to utilize our network of cooperating researchers along with paid or credit-earning student interns, pre-college student researchers, and citizen science volunteers working under the supervision of the researchers to collect the information and answer the research questions. This is a cost-effective process and has the added benefit of students (graduate or undergraduate) and local community

members being involved in research involving real world problems—a process through which they both learn about ecology and restoration and gain a stronger appreciation for conservation. The researchers have donated their services as an in-kind contribution to the project.

This assessment was conducted by the network of researchers from academic institutions at relatively low cost to the LGNC (with substantial support from the colleges in the form of equipment, consumable supplies, and staffing), and with tremendous educational value to undergraduate interns and graduate students which is another way this project has broader significance. Not only is our approach to restoration a model for others, but also our research and education network can also be emulated.

Numerous individuals, agencies, and organizations outside of academe have partnered with the LGNC to provide their expertise and other resources. Coordinating all of these

people and projects is, of course, a challenge, but without these collaborations, this project could not have come to fruition. The LGNC has developed a strong track record of conservation and restoration work, public outreach and education, and working collaboratively with a number of partners at the local, state and national levels. This is an important model for other conservation and ecological research groups to consider and has been essential to the completion of this assessment project and much of the other work of the organization. A list of the collaborators is included both in the acknowledge section and in Appendix A.

Subsequent chapters describe a range of different types of studies conducted by the various research groups and volunteers. Each research question required unique approaches, so the details of the experimental methodology are provided either in the chapter for that part of the project or in the related appendices.



## *Section II*

# *Biota of the Lehigh Gap Wildlife Refuge*

Part I of the ecological assessment focused largely on plant diversity and communities to give a sense of the types of ecosystems and habitat quality available. In addition, studies of lichen communities and faunal assessment of light-trapped insects were included. For the second assessment, greater emphasis was

placed on surveying vertebrate diversity at the Refuge. More thorough studies of the insect diversity, including a special emphasis on native bees, have been done. A complete list of the vertebrates observed on the Refuge property since 2002 is included as Appendix B in this document.

*Chapter 3*

*Biota of the Lehigh Gap  
Wildlife Refuge  
-- Mammals*

# LGWR Biota - Mammals

## Mammals of the LGWR

The mammal species list for Lehigh Gap Wildlife Refuge primarily includes species that have been observed on the Refuge as well as a few species that have been trapped in preliminary small mammal survey efforts. The first of these was conducted by Guthrie Mitchell from Lehigh University (see map on next page for location of traps).

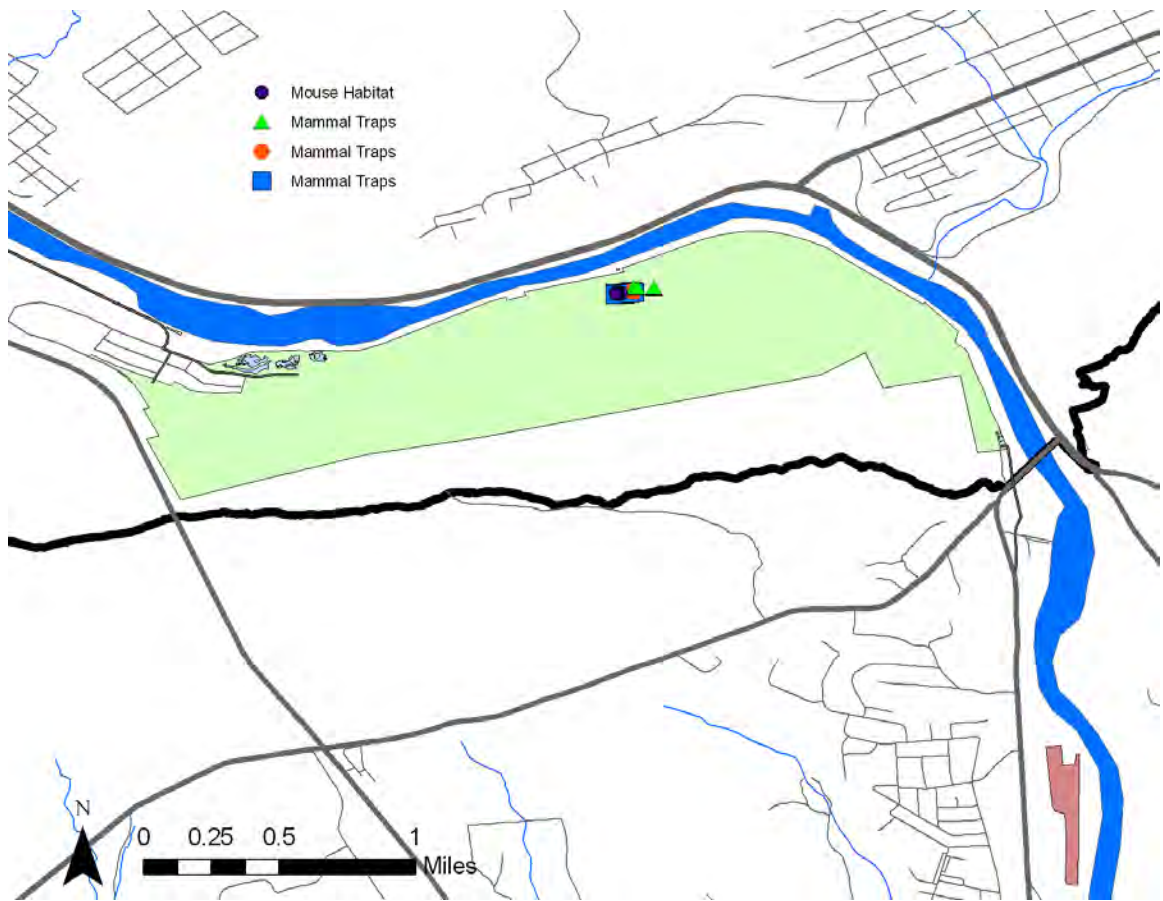


The 23 species sighted on the Refuge through December, 2010 include:

## Mammals of the Lehigh Gap Wildlife Refuge

Virginia Opossum  
(*Didelphis virginiana*)  
Northern Short-tailed Shrew  
(*Blarina brevicauda*)  
Little Brown Bat  
(*Myotis licifugus*)  
Red Bat  
(*Lasiurus borealis*)  
Eastern Cottontail  
(*Sylvilagus floridanus*)  
Eastern Chipmunk  
(*Tamias straitus*)  
Woodchuck  
(*Marmota monax*)  
Gray Squirrel  
(*Sciurus carolinensis*)  
Red Squirrel  
(*Tamiasciurus hudsonicus*)  
Beaver  
(*Castor canadensis*)  
White-footed Mouse  
(*Peromyscus leucopus*)

Meadow Vole  
(*Microtus pennsylvanicus*)  
Muskrat  
(*Ondatra zibethicus*)  
Porcupine  
(*Erethizon dorsatum*)  
Eastern Coyote  
(*Canis latrans*)  
Red Fox  
(*Vulpes vulpes*)  
Gray Fox  
(*Urocyon cinereargenteus*)  
Black Bear  
(*Ursus americanus*)  
Raccoon  
(*Procyon lotor*)  
Weasel sp.  
(*Mustela sp.*)  
Mink  
(*Mustela vison*)  
River Otter  
(*Lutra canadensis*)  
White-tailed Deer  
(*Odocoileus virginianus*)



**Location of Traps Used in Preliminary Small Mammal Trapping Study in the LGWR Grasslands.**

A more comprehensive small mammal survey of the Refuge involving small mammal trapping and photography was initiated in Fall 2010 by John Corbin under the supervision of Dr. Frank Kuserk from Moravian College. This study was conducted along the Lehigh & New England Trail, Delaware & Lehigh Trail, Three Ponds Trail, Prairie Grass Trail, Chestnut Oak Trail, and Double G Trail (see LGNC Trail Map on p. 1-9). The two methods used included setting 23 Sherman Live Traps out and using trail (game) cameras. The Sherman traps were set along the trails every 100 meters and were

baited with paste made of wild bird seed and beef fat. The following species were captured using the Sherman Traps: *Peromyscus* (this genus includes deer mice and white-footed mice; it is difficult to distinguish between the two species without skull and teeth measurements); Meadow Vole (*Microtus pennsylvanicus*); Short-tailed Shrew (*Blarina brevicauda*); and Eastern Chipmunk (*Tamias striatus*).

Ideally, this type of study could be repeated using a grid style trapping lay-out but comes with the risk of destroying the vegetation between

each trap which is checked every day for two weeks. This method was suggested by Rexford Lord, Ph.D. (zoologist and author of *The Mammals of South America* and *Capybara*) who is an advisor to the LGNC for the mammal project.

The second method involved the use of ir4 Trail-Game Cameras made by Wildgame Innovations. These trail cameras were set up along the before mentioned trails but far enough back to prevent visitors from seeing the cameras in an attempt to prevent theft. The exact locations were chosen by the presence of animal sign, intersections of game trails, presence of food sources, and access to water. Most locations were baited with fish oil or Russ Carman's Raccoon Lure #1 (sweet smelling). GPS coordinates of each camera were taken, but have not yet been mapped. The following species were photographed (see sample photos on page 3-7 below:

- Virginia Opossum (*Didelphis virginiana*) – near the Three Ponds Trail;
- Eastern Cottontail (*Sylvilagus floridanus*) – near the Lehigh River;
- Eastern Gray Squirrel (*Sciurus carolinensis*) – along the Chestnut Oak Trail;
- Muskrat (*Ondatra zibethicus*) – in the Three Ponds;
- Gray Fox (*Urocyon cinereoargenteus*) – near the Three Ponds Trail;
- Raccoon (*Procyon lotor*) – near the Three Ponds Trail;

- River Otter (*Lutra canadensis*) – near the Lehigh River;
- Black Bear (*Ursus americanus*) – near the Lehigh River
- White-tailed Deer (*Odocoileus virginianus*) – throughout the research area;
- Feral or Domesticated Cat (*Felis catus*) – along the Three Ponds Trail and the Double G Trail.

The feral or stray domestic cats are an important issue in terms of conservation management. Multiple photos of multiple cats on the Refuge have been obtained in Corbin's study and feral cats are known to have an impact on bird and small mammal populations.

The LGNC plans to do additional mammal surveys in the future. Given that small mammals form the base of the food chain for a variety of vertebrate predators, monitoring their population will help establish the viability of resident and migratory predator populations.

Dr. Lord has offered to assist in survey efforts by netting bats and has suggested a simple, yet comprehensive and effective means of surveying the diversity and abundance of mammal populations at LGWR. The method involves first live-trapping small mammals using baits such as peanut butter-oatmeal mix and apple slices. Each trapped mammal is placed in a garbage can with a sheet of plain white paper and an exposed inkpad. The animal runs across the pad and paper, leaving clean tracks on the paper. The

specimen is then released. This technique is repeated with each of the different species captured. This provides the researchers with a library of ink prints of native mammal species.

Once a collection of ink prints is created, floor tiles are covered with ink on one half and a sheet of paper on the other and set out in the mammal study areas. This survey can be done with bait to get an idea of what mammals inhabit the varied habitats as well as without bait to give us an idea of the density of the species. Unknown tracks will be identified to the extent possible with field guides; however, according to Dr. Lord, these books are difficult to use and problematic with small mammals for which they are generally not highly accurate.



The Carnegie Museum of Natural History maintains an online resource of the mammals of Pennsylvania.<sup>1</sup> This site includes a list of 70 species, distribution (range) maps, and other species data. The table on the next page identifies the number of species in each family of mammals that have published ranges covering the LGWR property (Carbon and Lehigh Counties) and indicates how many have been observed to date at the Refuge. The table suggests that the number of observed species of small mammals and nocturnal species are relatively low at the LGWR. It is not yet known if this is due to their absence or lack of a thorough study. Given the good habitat that now exists for small mammals and the number of snakes that have been observed on the property, it is suspected that the latter is the problem. This table may serve as a guide for target species in future studies.

---

<sup>1</sup> See <http://www.carnegiemnh.org/mammals/PAmamm/pamammals2.html>).

## Mammals of Lehigh and Carbon Counties and the Lehigh Gap Wildlife Refuge

| Family                                | Number of species whose distribution (range) includes the LGWR property (of total species in that family in PA) <sup>2</sup> | Number and percentage of species from a family that have been seen at the LGWR as of 12/1/10 |
|---------------------------------------|------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|
| Pouched mammals (Marsupialia)         | 1 (of 1)                                                                                                                     | 1 (100%)                                                                                     |
| Shrew family (Soricida)               | 6 (of 7)                                                                                                                     | 1 (17%)                                                                                      |
| Mole family (Talpidae)                | 3 (of 3)                                                                                                                     | 0 (0%)                                                                                       |
| Evening bat family (Vespertilionidae) | 8 (of 10)                                                                                                                    | 2 (25%)                                                                                      |
| Rabbits and hares (Lagomorpha)        | 3 (of 3)                                                                                                                     | 1 (33%)                                                                                      |
| Squirrel family (Sciuridae)           | 5 (of 8)                                                                                                                     | 4 (80%)                                                                                      |
| Beaver family (Castoridae)            | 1 (of 1)                                                                                                                     | 1 (100%)                                                                                     |
| New World rats and mice (Cricetinae)  | 8 (of 9)                                                                                                                     | 3 (37%)                                                                                      |
| Old World rats and mice (Murinae)     | 2 (of 3)                                                                                                                     | 0 (0%)                                                                                       |
| Jumping mice family (Zapodidae)       | 2 (of 2)                                                                                                                     | 0 (0%)                                                                                       |
| Porcupine family (Erethizontidae)     | 0 (of 1)                                                                                                                     | 1*                                                                                           |
| Dog family (Canidae)                  | 3 (of 3)                                                                                                                     | 3 (100%)                                                                                     |
| Raccoon family (Procyonidae)          | 1 (of 1)                                                                                                                     | 1 (100%)                                                                                     |
| Bear family (Ursidae)                 | 1 (of 1)                                                                                                                     | 1 (100%)                                                                                     |
| Weasel family (Mustelidae)            | 5 (of 10)                                                                                                                    | 3 (60%)                                                                                      |
| Cat family (Felidae)                  | 1 (of 1)                                                                                                                     | 0 (0%)                                                                                       |
| Deer family (Cervidae)                | 1 (of 1)                                                                                                                     | 1 (100%)                                                                                     |

<sup>2</sup> Table compiled from species lists and distribution maps found at <http://www.carnegiemnh.org/mammals/PAmamm/pamammals2.html> <accessed on 12/27/10> and documented sightings from the LGWR. Species for which no range maps are included at the Carnegie site were excluded from this table.

\* The range map for porcupines does not currently cover lower Carbon or Lehigh counties but these have been observed at the refuge.





Sample Trail Camera Images from the Lehigh Gap Wildlife Refuge



In addition to the small mammal surveys, the impact of deer browsing on the Refuge is being studied. Forested areas of the Refuge appear to be over-browsed. Deer exclosures have been installed in the forested areas to study the regeneration of plants inside the fences where deer grazing is excluded. In addition, the effect of deer browsing on the grassland enhancement effort is being studied (see maps on next two pages, Chapter 8 and Appendix F-2).

The LGNC had an offer of the use of an airplane and pilot to do winter aerial deer surveys to get an actual count of deer numbers on the Refuge and surrounding area. An experimental aerial surveillance with a single-engine Cessna aircraft was performed in January 2010 with the ground covered by snow. No deer were spotted from the air, even though there was excellent visibility on much of the Refuge.

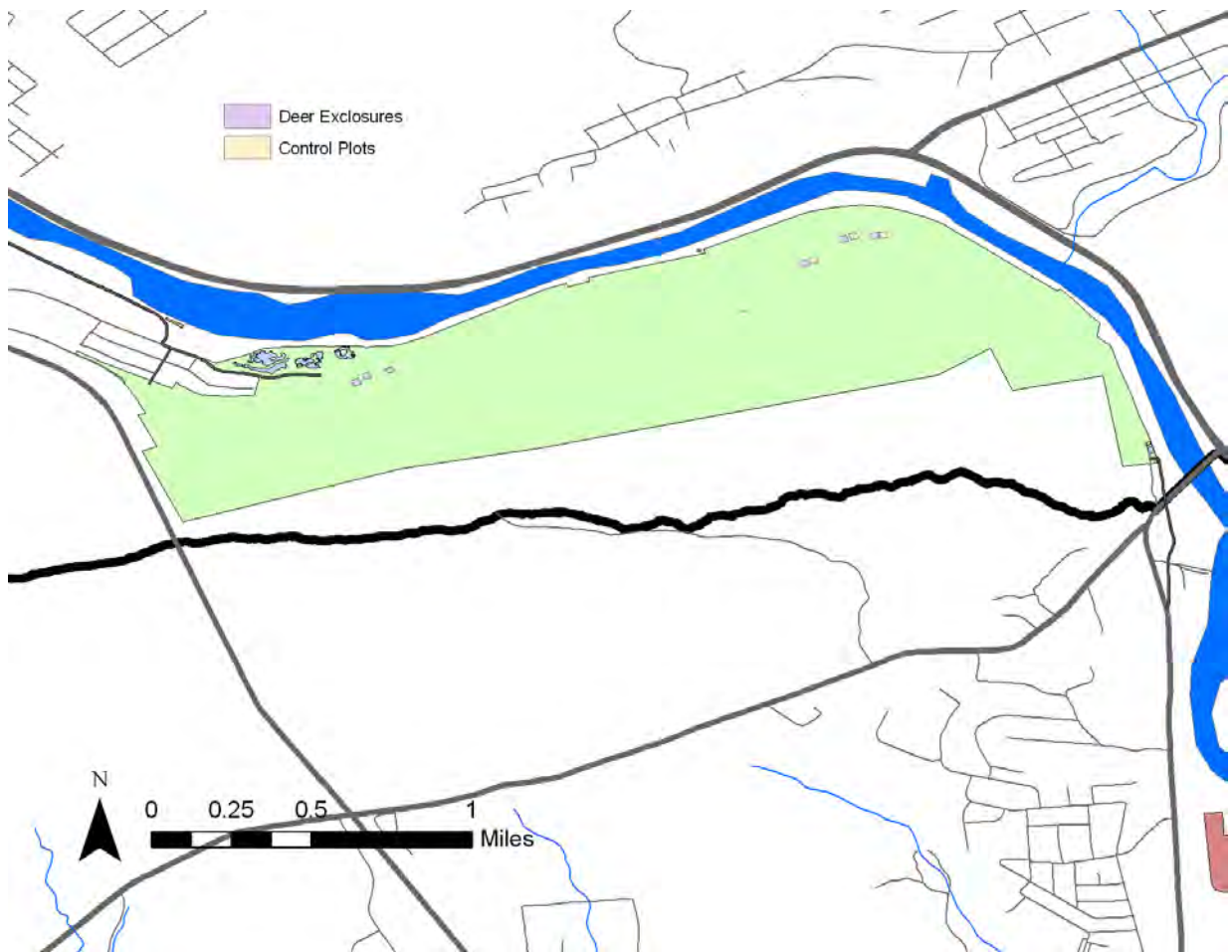


**Exclosure in Forested (Western) Area of the LGWR**

Bats are of particular concern because of the recent decline in bat numbers due, at least in part, to the White-nose Syndrome (WNS). This past year, in the late morning of March 27, 2010, a little brown bat was seen flying erratically near the Visitor and Education Center. After hitting the house windows a few times and perching on a utility pole, it flew behind the second floor shutter. Given that this animal was spotted in the daylight on a cold day and the erratic behavior displayed both suggest that the bat was affected with WNS.

One final mammal species warrants attention: the Allegheny Woodrat (*Neotoma magister*). Woodrats live in other rocky areas along the Kittatinny Ridge and it is possible that there are woodrats somewhere on the Refuge or adjacent National Park Service or PA Game Commission properties. Woodrats traditionally eat the fruit of American Chestnuts, which are in the region, including Refuge property. A comprehensive Eastern Woodrat survey of likely habitats within the Refuge is planned for the near future.





**Location of Deer Exlosures on the LGWR property**  
(See also zoomed-in map of exclosures on next page)



**Location of Deer Exclosures on the LGWR property - a Zoomed-In Image**



**Grassland Deer Exclosure**

## *Chapter 4*

# *Biota of the Lehigh Gap Wildlife Refuge – Reptiles and Amphibians*

# *LGWR Biota – Reptiles and Amphibians*

Reptiles and amphibians are particularly sensitive to their environment and thus, are important indicators of the quality of their habitat and any changes in the environment. To date, only visual surveys have been conducted with a

total of 29 species having been identified. Sean Bankos, one of the Naturalist Club members, did weekly surveys in spring and summer of 2009 in an attempt to do a more thorough analysis of which species exist on the property.

## **Reptiles and Amphibians of the Lehigh Gap Wildlife Refuge**

### Snapping Turtle

(*Chelydra serpentina*)

### Eastern Painted Turtle

(*Chrysemys picta*)

### Spotted Turtle

(*Clemmys guttata*)

### Wood Turtle

(*Clemmys insculpta*)

### Eastern Box Turtle

(*Terrapene carolina*)

### Common Musk Turtle

(*Sternotherus odoratus*)

### Five-lined Skink

(*Eumeces fasciatus*)

### Northern Racer

(*Coluber constrictor*)

### Eastern Rat Snake

(*Pantherophis alleghaniensis*)

### Eastern Hognose Snake

(*Heterodon platirhinos*)

### Northern Water Snake

(*Nerodia sipedon*)

### Eastern Garter Snake

(*Thamnophis sirtalis*)

### Northern Copperhead

(*Agkistrodon contortix*)

### Timber Rattlesnake

(*Crotalus horridus*)

### American Toad

(*Anaxyrus americanus*)

### Gray Treefrog

(*Hyla versicolor*)

### Bullfrog

(*Lithobates catesbeianus*)

### Green Frog

(*Lithobates clamitans*)

### Pickerel Frog

(*Lithobates palustris*)

### Wood Frog

(*Lithobates sylvaticus*)

### Northern Spring Peeper

(*Pseudacris crucifer*)

### Northern Dusky Salamander

(*Desmognathus fuscus*)

### Mountain Dusky Salamander

(*Desmognathus ochrophaeus*)

### Northern Two-lined Salamander

(*Eurycea bislineata*)

### Long-tailed Salamander

(*Eurycea longicauda*)

### Four-toed Salamander

(*Hemidactylium scutatum*)

### Northern Red-backed Salamander

(*Plethodon cinereus*)

### Northern Red Salamander

(*Pseudotriton ruber*)

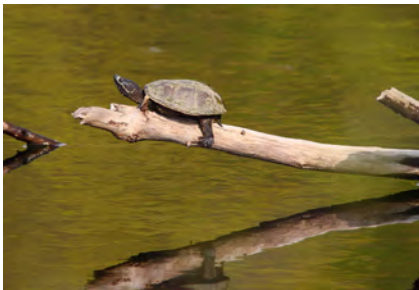
### Eastern (Red-spotted) Newt

(*Notophthalmus viridescens*)



In reviewing the Pennsylvania Herpetological Society Species Lists<sup>1</sup> for salamanders of Carbon and Lehigh Counties, 7 of 11 of the Lehigh County species and 6 of the 11 Carbon County species have been observed at the LGWR. Marbled (Lehigh only), Spotted, Jefferson's, Spring and Northern Slimy Salamanders exist in this region, but have not been seen at the Refuge. Of frogs and toads, 7 of 10 and 7 of 11 species from the Carbon and Lehigh Counties lists, respectively, have been observed at the LGWR. Fowlers Toad, Western Chorus Frog (Lehigh only), Upland Chorus Frog, Northern Leopard Frog (Lehigh only) and Eastern Spadefoot (Carbon only) are confirmed in the region but have not been observed at the Refuge.

All turtle species recorded in the counties, except the Bog Turtle, have been spotted at the LGWR; but it should be noted that this rare species has not been reported anywhere in Carbon County. Interestingly, the Common Musk Turtle, which is frequently seen at the ponds on the west side of the Refuge, is not on the list of a confirmed turtle species for Carbon County on the PA Herpetological Society site.



**Common Musk Turtle**

<sup>1</sup> See [www.paherps.com](http://www.paherps.com) and <http://www.paherp.org/app/>.

For snakes, 7 of 10 Lehigh County species and 6 of 11 Carbon County species have been observed at the LGWR. The Northern Ringneck, Eastern Milk, DeKay's Brown (Lehigh only), Red-bellied (Carbon only) and Smooth Green (Carbon only) snakes have not been observed at the Refuge. The only lizard on either county list, the Five-lined Skink, has been seen at the LGWR.

The pond to the immediate south of the Osprey House has been an important habitat for amphibians. Over the years, the lining of the pond and changes in water flow to the pond have led to decreasing water levels, especially in the summer. In fall 2010, major restoration work on the pond was completed. During the process, most of the non-native parrot's feather (*Myriophyllum aquaticum*) was removed. However, in the process of the restoration, some species may have been lost, despite attempts to relocate as many animals into a temporary holding pond as possible. The impact of this work will have to be monitored in 2011 and beyond.



**Bullfrog**

The skinks and snakes have often been observed amongst the rocks of the habitat gardens and that form a wall along the upper drive by the Osprey House. In order to prevent

damaging water flow into the Osprey House, major roadwork and a new rock support wall was build in 2010. Hopefully, the new stone wall will provide good habitat for these species.



**Eastern (Red-spotted) Newt**

Reptiles and amphibians have also been found along temporary puddles that form from the seeps along the edge of the LNE rail bed, in the area of the ponds on the west end of the Refuge property, and along the riparian zone of the Lehigh River.



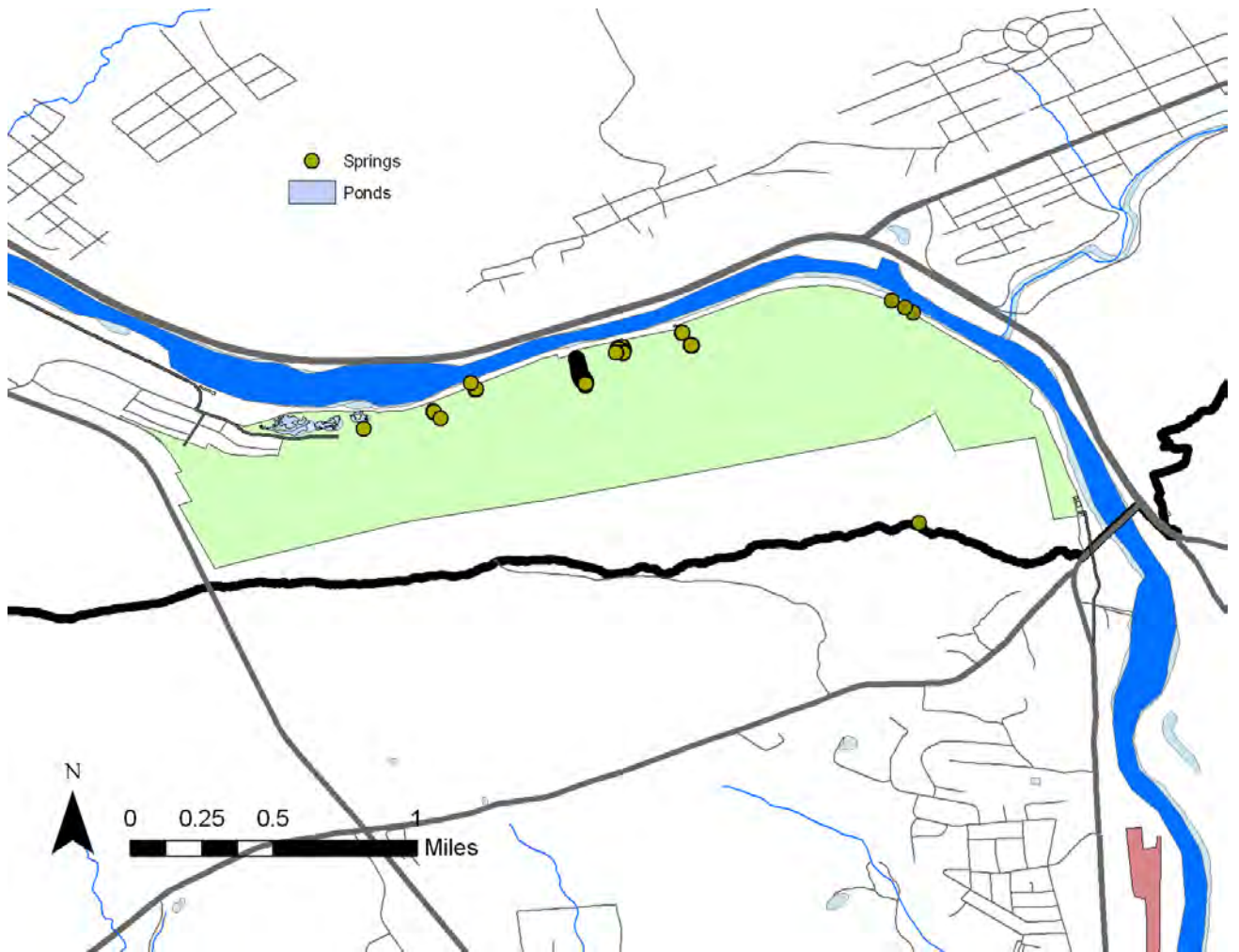
**Pickerel Frog**

A map of the key water features (springs and ponds) of the Refuge is shown on the following page. In the LGWR Ecological Assessment – Part I, there is a map of the LGWR wetland areas (page 15); all of these are in the

vicinity of the ponds on the west end of the property.

Ideally, in the near future, more systematic surveys for salamanders can be conducted in the spring especially in the area of the vernal pools. Amphibians are likely to be more susceptible to harm from metals contamination and acid deposition than other vertebrates, so monitoring them could be useful in understanding the continuing impact, if any, of such environmental pollutants at the Refuge. Additionally, with predictions of a warming climate, reptiles and amphibians might become important bio-indicators of changing conditions on the Refuge property.





**Water Features Located Within the LGWR**





**A Seep along the D&L Trail**

## *Chapter 5*

# *Biota of the Lehigh Gap Wildlife Refuge – Birds*





# LGWR Biota - Birds

## A Survey of the Birds at LGWR

The following information is occurrence data for the birds of the LGWR. The data was collected during bird surveys conducted by Corey, Diane, and Dave Husic as well as Dan Kunkle. The data presented is from 77 surveys conducted between March 2006 and May 2009.



**Blue Grosbeak**

Over 31,000 birds of 139 species were recorded during the survey. The highest species count on a single survey was on October 5, 2008 with 59 species. The highest bird count in a single day was on March 14, 2007 with 5,676 individual birds. Surveys were conducted around the nature center grounds, along the Prairie Warbler Trail, and on the Osprey Loop (consisting of transects along the LNE, Bobolink, and D&L Trails; see map at end of this chapter). Transect data can be used as a baseline to monitor changes in various sections of the Refuge (different habitats) over time.

The data on subsequent pages is split into four seasons: spring,

summer, fall, and winter. Occurrence is displayed as percentages; the percent of surveys on which the particular species has been observed. Occurrence terms: rare, uncommon, fairly common, and common, are used as well. A high count is also given for each species. This number is the most individuals of a single species that has been seen on a single survey.

Other bird sightings have been recorded at the Refuge throughout the past seven years by the study authors and others, but only those sightings from the formal surveys are included in the data below. A complete list of all bird species (164 total) observed to date throughout the entire Refuge property can be found in Appendix B.

Species that require grasslands to breed, are noted as *grassland species*. Species that are extremely common some years, but absent in others are listed as *irruptive species*. Because of this irruptive behavior, this occurrence data may be misleading.



**Prairie Warbler**

Order and nomenclature follows the American Birding Association Checklist, Version 7.0.

**Spring**-March, April, May

**Summer**-June, July, August

**Fall**-September, October, November

**Winter**-December, January, February

**Rare**- seen on 6% or less of surveys

**Uncommon**- seen on more than 6% and less than 50% of surveys

**Fairly common**- seen on 50% or more and less than 90% of surveys

**Common**- seen on 90% or more of surveys

**Snow Goose** spring-uncommon (11%); summer-no record; fall-no record; winter-uncommon (14%); high count: 4520 on February 14, 2009

**Ross's Goose** one record, March 14, 2007

**Canada Goose** spring-fairly common (89%); summer-fairly common (53%); fall-fairly common (52%); winter-fairly common (86%); high count: 1886 on March 14, 2007

**Wood Duck** spring-uncommon (11%); summer-rare (5.9%); fall-no record; winter-no record; high count: 2 on March 14, 2007 and August 3, 2008

**American Black Duck** spring-uncommon (11%); summer-no record; fall-rare (4.4%); winter-fairly common (57%); high count: 4 on March 17, 2008; November 28, 2008; and December 26, 2008

**Mallard** spring-fairly common (79%); summer-uncommon (47%); fall-uncommon (35%); winter-uncommon (43%); high count: 13 on March 28, 2009

**Ring-necked Duck** one record, 2 on March 3, 2007

**Bufflehead** spring-no record; summer-no record; fall-uncommon (8.7%); winter-no record; high count: 5 on November 2, 2008

**Hooded Merganser** one record, 1 on April 6, 2007

**Common Merganser** spring-common (93%); summer-fairly common (59%); fall-uncommon (26%); winter-common (100%); high count: 30 on August 12, 2007

**Ring-necked Pheasant** one record, 1 on October 1, 2006; *grassland species*

**Common Loon** spring-uncommon (14%); summer-no record; fall-rare (4.4%); winter-no record; high count: 17 on April 13, 2008

**Double-crested Cormorant** spring-uncommon (14%); summer-rare (5.9%); fall-uncommon (17%); winter-no record; high count: 13 on May 5, 2007

**Great Blue Heron** spring-uncommon (14%); summer-uncommon (12%); fall-uncommon (17%); winter-no record; high count: 6 on October 5, 2008

**Green Heron** spring-no record; summer-uncommon (12%); fall-no record; winter-no record; high count: 1 on June 24, 2007 and August 9, 2008

**Black Vulture** spring-fairly common (57%); summer-uncommon (18%); fall-rare (4.4%); winter-no record; high count: 6 on April 6, 2008

**Turkey Vulture** spring-common (93%); summer-fairly common (76%); fall-fairly common (61%); winter-no record; high count: 49 on April 13, 2008

**Osprey** spring-uncommon (21%); summer-uncommon (24%); fall-uncommon (30%); winter-no record; high count: 8 on April 19, 2009

**Bald Eagle** spring-uncommon (14%); summer-uncommon (41%); fall-uncommon (13%); winter-uncommon (14%); high count: 3 on August 12, 1007

**Northern Harrier** spring-rare (3.6%); summer-no record; fall-rare (4.4%); winter-uncommon (14%); high count: 2 on April 19, 2009; *grassland species*

**Sharp-shinned Hawk** spring-uncommon (21%); summer-uncommon (18%); fall-fairly common (52%); winter-uncommon (29%); high count: 12 on October 5, 2008

**Cooper's Hawk** spring-no record; summer-uncommon (12%); fall-uncommon (17%); winter-no record; high count: 1 on October 28, 2007; August 3, 2008; August 24, 2008; September 1, 2008; September 7, 2008; and October 26, 2008

**Northern Goshawk** one record, 1 on May, 18, 2008

**Red-shouldered Hawk** spring-uncommon (7.1%); summer-rare (5.9%); fall-rare (4.4%); winter-no record; high count: 10 on March 14, 2007

**Broad-winged Hawk** spring-uncommon (7.1%); summer-rare (5.9%); fall-uncommon (8.7%); winter-no record; high count: 17 on April 19, 2009

**Red-tailed Hawk** spring-uncommon (46%); summer-fairly common (65%); fall-fairly common (57%); winter-uncommon (43%); high count: 6 on November 16, 2008

**Rough-legged Hawk** one record, 1 on February 24, 2008; *grassland species*

**Golden Eagle** spring-no record; summer-no record; fall-uncommon (8.7%); winter-no record; high count: 1 on October 28, 2007 and November 2, 2008

**American Kestrel** spring-fairly common (57%); summer-fairly common (76%); fall-uncommon (43%); winter-uncommon (14%); high count: 5 on April 19, 2009; *grassland species*

**Merlin** spring-no record; summer-rare (5.9%); fall-uncommon (26%); winter-no record; high count: 3 on September 14, 2008

**Peregrine Falcon** spring-rare (3.6%); summer-rare (5.9%); fall-uncommon (8.7%); winter-no record; high count: 2 on October 5, 2008

**Killdeer** spring-uncommon (29%); summer-uncommon (47%); fall-no record; winter-no record; high count: 3 on May 20, 2007

**Spotted Sandpiper** spring-uncommon (7.1%); summer-uncommon (18%); fall-uncommon (8.7%); winter-no record; high count: 9 on May 20, 2007

**Ring-billed Gull** spring-uncommon (25%); summer-no record; fall-rare (4.4%); winter-uncommon (29%); high count: 121 on January 28, 2007

**Herring Gull** spring-uncommon (11%); summer-no record; fall-uncommon (8.7%); winter-fairly common (57%); high count: 19 on January 27, 2008

**Great Black-backed Gull** one record, 1 on January 27, 2008

**Rock Pigeon** spring-fairly common (71%); summer-fairly common (71%); fall-common (91%); winter-fairly common (86%); high count: 70 on November 2, 2008

**Mourning Dove** spring-common (100%); summer-common (100%); fall-common (96%); winter-common (100%); high count: 24 on May 3, 2008

**Yellow-billed Cuckoo** spring-uncommon (7.1%); summer-uncommon (18%); fall-rare (4.4%); winter-no record; high count: 2 on May 26, 2007 and June 14, 2007

**Chimney Swift** spring-uncommon (25%); summer-fairly common (65%); fall-uncommon (8.7%); winter-no record; high count: 62 on August 24, 2008

**Ruby-throated Hummingbird** spring-uncommon (18%); summer-fairly common (88%); fall-uncommon (22%); winter-no record; high count: 7 on August 12, 2007

**Belted Kingfisher** spring-uncommon (36%); summer-uncommon (41%); fall-uncommon (26%); winter-uncommon (14%); high count: 3 on March 28, 2009

**Red-bellied Woodpecker** one record, 1 on November 2, 2008

**Yellow-bellied Sapsucker** one record, 1 on October 1, 2006

**Downy Woodpecker** spring-uncommon (43%); summer-fairly common (65%); fall-common (91%); winter-fairly common (71%); high count: 11 on November 26, 2006

**Hairy Woodpecker** spring-uncommon (7.1%); summer-no record; fall-uncommon (8.7%); winter-uncommon (14%); high count: 1 on April 16, 2006; November 4, 2007; April 6, 2008; September 21, 2008; and February 14, 2009

**Northern Flicker** spring-uncommon (29%); summer-uncommon (29%); fall-uncommon (26%); winter-no record; high count: 27 on April 19, 2009

**Pileated Woodpecker** one record, 1 on June 1, 2008

**Eastern Wood-Pewee** spring-rare (3.6%); summer-uncommon (18%); fall-rare (4.4%); winter-no record; high count: 1 on May 20, 2006; September 10, 2006; June 24, 2007; July 1, 2007; and August 26, 2007

**Least Flycatcher** one record, 2 on May 5, 2007

**Eastern Phoebe** spring-fairly common (86%); summer-fairly common (88%); fall-fairly common (52%); winter-no record; high count: 20 on April 6, 2007

**Great Crested Flycatcher** spring-uncommon (21%); summer-uncommon (29%); fall-no record; winter-no record; high count: 2 on June 3, 2007 and June 14, 2007

**Eastern Kingbird** spring-uncommon (25%); summer-fairly common (88%); fall-uncommon (8.7%); winter-no record; high count: 75 on August 12, 2007

**Blue-headed Vireo** spring-no record; summer-no record; fall-uncommon (22%); winter-no record; high count: 5 on October 5, 2008

**Warbling Vireo** spring-uncommon (29%); summer-uncommon (41%) fall-uncommon (17%); winter-no record; high count: 4 on June 24, 2007

**Philadelphia Vireo** one record, 2 on May 28, 2006

**Red-eyed Vireo** spring-uncommon (36%); summer-fairly common (88%); fall-uncommon (35%); winter-no record; high count: 14 on June 3, 2007

**Blue Jay** spring-fairly common (75%); summer-fairly common (59%); fall-fairly common (83%); winter-uncommon (43%); high count: 174 on September 23, 2007

**American Crow** spring-common (100%); summer-common (100%); fall-fairly common (87%); winter-common (100%); high count: 154 on November 2, 2008



**Fish Crow** spring-uncommon (21%); summer-rare (5.9%); fall-no record; winter-no record; high count: 6 on May 20, 2006

**Common Raven** spring-uncommon (11%); summer-uncommon (18%); fall-uncommon (26%); winter-uncommon (29%); high count: 3 on June 1, 2008

**Tree Swallow** spring-fairly common (82%); summer-fairly common (82%); fall-uncommon (17%); winter-no record; high count: 204 on September 7, 2008

**Northern Rough-winged Swallow** spring-fairly common (57%); summer-fairly common (65%); fall-rare (4.4%); winter-no record; high count: 45 on May 3, 2008

**Bank Swallow** spring-rare (3.6%); summer-uncommon (24%); fall-no record; winter-no record; high count: 2 on May 28, 2006

**Barn Swallow** spring-uncommon (36%); summer-fairly common (53%); fall-uncommon (17%); winter-no record; high count: 7 on September 2, 2007

**Carolina Chickadee** one record, 1 on December 21, 2006

**Black-capped Chickadee** spring-common (93%); summer-fairly common (71%); fall-common (91%); winter-common (100%); high count: 26 on September 23, 2007

**Tufted Titmouse** spring-fairly common (82%); summer-fairly common (82%); fall-fairly common (78%); winter-common (100%); high count: 15 on June 17, 2006

**Red-breasted Nuthatch** one record, 1 on October 26, 2008

**White-breasted Nuthatch** spring-uncommon (21%); summer-uncommon (18%); fall-uncommon (43%); winter-uncommon (43%); high count: 4 on June 24, 2007

**Brown Creeper** spring-uncommon (7.1%); summer-no record; fall-rare (4.4%); winter-no record; high count: 1 on March 14, 2007; April 1, 2007; and October 5, 2008

**Carolina Wren** spring-fairly common (79%); summer-common (94%); fall-common (96%); winter-common (100%); high count: 8 on August 12, 2007 and October 13, 2007

**House Wren** spring-uncommon (25%); summer-uncommon (41%); fall-uncommon (26%); winter-no record; high count: 7 on September 14, 2008

**Golden-crowned Kinglet** spring-uncommon (14%); summer-no record; fall-uncommon (35%); winter-no record; high count: 11 on November 5, 2006

**Ruby-crowned Kinglet** spring-uncommon (14%); summer-no record; fall-uncommon (48%); winter-no record; high count: 24 on October 1, 2006

**Blue-gray Gnatcatcher** spring-uncommon (14%); summer-uncommon (41%); fall-rare (4.4%); winter-no record; high count: 2 on May 5, 2007; May 20, 2007; May 26, 2007; June 3, 2007; June 14, 2007; and May 3, 2008

**Eastern Bluebird** spring-fairly common (86%); summer-fairly common (88%); fall-fairly common (61%); winter-uncommon (43%); high count: 41 on October 5, 2008

**Swainson's Thush** one record, 1 on May 20, 2007

**Hermit Thrush** one record, 1 on October 9, 2006

**American Robin** spring-fairly common (75%); summer-fairly common (71%); fall-fairly common (65%); winter-uncommon (29%); high count: 379 on October 5, 2008

**Gray Catbird** spring-uncommon (39%); summer-common (94%); fall-fairly common (52%); winter-no record; high count: 17 on June 24, 2007 and May 25, 2009

**Northern Mockingbird** spring-fairly common (57%); summer-fairly common (82%); fall-uncommon (22%); winter-uncommon (29%); high count: 8 on June 24, 2007

**Brown Thrasher** one record, 1 on August 24, 2008

**European Starling** spring-uncommon (39%); summer-uncommon (47%); fall-uncommon (22%); winter-no record; high count: 133 on June 21, 2006

**Cedar Waxwing** spring-uncommon (14%); summer-fairly common (82%); fall-uncommon (43%); winter-no record; high count: 37 on October 5, 2008

**Blue-winged Warbler** spring-rare (3.6%); summer-no record; fall-rare (4.4%); winter-no record; high count: 1 on May 20, 2006 and September 10, 2006

**Tennessee Warbler** spring-no record; summer-rare (5.9%); fall-rare (4.4%); winter-no record; high count: 2 on August 20, 2006

**Orange-crowned Warbler** one record, 1 on October 5, 2008

**Nashville Warbler** spring-no record; summer-no record; fall-uncommon (13%); winter-no record; high count: 4 on September 10, 2006

**Northern Parula** spring-no record; summer-no record; fall-uncommon (8.7%); winter-no record; high count: 3 on October 5, 2008

**Yellow Warbler** spring-uncommon (43%); summer-fairly common (71%); fall-no record; winter-no record; high count: 18 on May 20, 2007 and May 26, 2007

**Chestnut-sided Warbler** spring-no record; summer-rare (5.9%); fall-uncommon (8.7%); winter-no record; high count: 1 on August 20, 2006; September 12, 2006; and October 1, 2006

**Magnolia Warbler** spring-no record; summer-rare (5.9%); fall-uncommon (26%); winter-no record; high count: 3 on August 20, 2006

**Cape May Warbler** one record, 1 on October 5, 2008

**Black-throated Blue Warbler** spring-rare (3.6%); summer-no record; fall-uncommon (17%); winter-no record; high count: 7 on October 5, 2008

**Yellow-rumped Warbler** spring-uncommon (11%); summer-no record; fall-uncommon (30%); winter-no record; high count: 6 on October 5, 2008

**Black-throated Green Warbler** spring-uncommon (7.1%); summer-rare (5.9%); fall-uncommon (39%); winter-no record; high count: 29 on October 1, 2006

**Blackburnian Warbler** one record, 3 on October 5, 2008

**Pine Warbler** spring-rare (3.6%); summer-no record; fall-rare (4.4%); winter-no record; high count: 1 on April 29, 2006 and September 10, 2006

**Prairie Warbler** spring-uncommon (46%); summer-common (94%); fall-uncommon (30%); winter-no record; high count: 20 on May 5, 2007

**Palm Warbler** spring-uncommon (11%); summer-no record; fall-uncommon (8.7%); winter-no record; high count: 5 on May 5, 2007

**Bay-breasted Warbler** one record, 1 on October 5, 2008

**Blackpoll Warbler** spring-uncommon (7.1%); summer-no record; fall-uncommon (13%); winter-no record; high count: 20 on October 5, 2008

**Black-and-white Warbler** spring-uncommon (46%); summer-common (94%); fall-rare (4.4%); winter-no record; high count: 9 on May 3, 2008

**American Redstart** spring-uncommon (11%); summer-uncommon (24%); fall-rare (4.4%); winter-no record; high count: 5 on May 20, 2006

**Worm-eating Warbler** spring-uncommon (7.1%); summer-rare (5.9%); fall-no record; winter-no record; high count: 1 on May 3, 2006; May 18, 2008; and May 25, 2009

**Mourning Warbler** spring-rare (3.6%); summer-rare (5.9%); fall-no record; winter-no record; high count: 1 on May 28, 2006 and June 1, 2008

**Common Yellowthroat** spring-uncommon (39%); summer-fairly common (76%); fall-uncommon (43%); winter-no record; high count: 10 on September 2, 2007

**Canada Warbler** one record, 1 on August 26, 2007

**Scarlet Tanager** spring-uncommon (14%); summer-uncommon (12%); fall-uncommon (22%); winter-no record; high count: 3 on May 18, 2009

**Eastern Towhee** spring-fairly common (50%); summer-fairly common (82%); fall-uncommon (30%); winter-no record; high count: 6 on October 5, 2008

**American Tree Sparrow** spring-rare (3.6%); summer-no record; fall-rare (4.4%); winter-uncommon (14%); high count: 2 on February 24, 2008

**Chipping Sparrow** spring-fairly common (57%); summer-common (100%); fall-fairly common (65%); winter-no record; high count: 61 on October 13, 2007

**Field Sparrow** spring-fairly common (61%); summer-fairly common (76%); fall-fairly common (74%); winter-no record; high count: 40 on September 4, 2006

**Vesper Sparrow** spring-no record; summer-no record; fall-uncommon (8.7%); winter-no record; high count: 1 on November 5, 2006 and October 26, 2008; *grassland species*

**Savannah Sparrow** spring-no record; summer-no record; fall-uncommon (17%); winter-no record; high count: 2 on September 21, 2008; *grassland species*

**Grasshopper Sparrow** one record, 1 on September 10, 2006; *grassland species*

**Fox Sparrow** spring-rare (3.6%); summer-no record; fall-rare (4.4%); winter-no record; high count: 4 on November 2, 2008

**Song Sparrow** spring-common (100%); summer-common (100%); fall-common (100%); winter-common (100%); high count: 48 on March 30, 2008

**Swamp Sparrow** one record, 1 on October 5, 2008

**White-throated Sparrow** spring-uncommon (36%); summer-no record; fall-fairly common (52%); winter-fairly common (57%); high count: 60 on November 5, 2006

**White-crowned Sparrow** one record, 1 on November 4, 2007

**Dark-eyed Junco** spring-fairly common (71%); summer-uncommon (35%); fall-fairly common (57%); winter-common (100%); high count: 157 on November 2, 2008

**Northern Cardinal** spring-common (96%); summer-common (100%); fall-common (91%); winter-fairly common (71%); high count: 14 on September 7, 2008

**Rose-breasted Grosbeak** spring-no record; summer-rare (5.9%); fall-uncommon (13%); winter-no record; high count: 2 on September 10, 2006 and September 12, 2006

**Blue Grosbeak** one record, 1 on August 9, 2008; *grassland species; first Carbon County breeding record*

**Indigo Bunting** spring-uncommon (32%); summer-common (94%); fall-uncommon (17%); winter-no record; high count: 23 on May 25, 2009

**Red-winged Blackbird** spring-common (93%); summer-fairly common (82%); fall-uncommon (8.7%); winter-uncommon (14%); high count: 401 on March 17, 2008

**Eastern Meadowlark** one record, 2 on March 28, 2009; *grassland species*

**Common Grackle** spring-fairly common (57%); summer-fairly common (76%); fall-uncommon (8.7%); winter-no record; high count: 100 on August 20, 2006

**Brown-headed Cowbird** spring-fairly common (68%); summer-fairly common (65%); fall-uncommon (8.7%); winter-uncommon (14%); high count: 54 on October 14, 2006

**Orchard Oriole** spring-rare (3.6%); summer-rare (5.9%); fall-no record; winter-no record; high count: 3 on May 25, 2009

**Baltimore Oriole** spring-uncommon (39%); summer-fairly common (82%); fall-rare (4.4%); winter-no record; high count: 9 on May 20, 2007 and May 18, 2009

**Purple Finch** spring-no record; summer-uncommon (12%); fall-uncommon (8.7%); winter-no record; high count: 1 on June 4, 2006; June 1, 2008; and November 28, 2008; *irruptive species*

**House Finch** spring-fairly common (61%); summer-fairly common (76%); fall-fairly common (74%); winter-fairly common (57%); high count: 38 on October 5, 2008

**White-winged Crossbill** one record, 2 on February 14, 2009; *irruptive species*



**Common Redpoll** one record, 37 on November 25, 2007; *irruptive species*

**Pine Siskin** spring-uncommon (11%); summer-no record; fall-uncommon (17%); winter-uncommon (29%); high count: 531 on November 2, 2008; irruptive species

**American Goldfinch** spring-fairly common (75%); summer-common (94%); fall-common (96%); winter-uncommon (29%); high count: 60 on December 26, 2008

**House Sparrow** spring-rare (3.6%); summer-uncommon (12%); fall-no record; winter-no record; high count: 2 on June 14, 2007 and June 1, 2008



**American Goldfinch**

Two previous bird studies have been conducted in the Lehigh Gap area: one in 1900-1903 (Rehn, 1903)<sup>1</sup> and one in 1982-1983 (Reed 1984)<sup>2</sup>. Rehn conducted his survey just a few years after the zinc smelting industry began in the region (1898) – long before most of the damage was done. Additionally, the chestnut blight, which eliminated the once common American Chestnut trees from the region, had not yet been introduced. Reed conducted his study in the early 1980s after the smelters had been shut down and at a point when the environmental damage was at its worse. Both studies were conducted during the summer months (June, July, August) as opposed to the most recent longitudinal study, which was conducted year-round. It is difficult to directly compare results from the studies for a number of reasons. Rehn and Reed did not count individuals, only species, and they did not define the limits of their study areas. However, based on some of their sightings, they must have included some forested areas in their surveys, and in Rehn's case, nearby farms. The Husic study was conducted in the area around the Osprey House, the shrub habitat in the Prairie Warbler trail area, in the restoration area, and along the old rail beds where primary succession is occurring.



**Scrub Habitat in the  
Prairie Warbler Trail Area**

To compare the current results with the previous findings, only data collected in June, July, and August of 2006 and June of 2007 were compared. (Note: Reed's surveys were conducted primarily in those same months over two years, but he also had one survey date in April and one in May.) All current bird names used are from Peterson (2002)<sup>3</sup>.

During the summers of 2006 and 2007, a total of 76 different species were observed during the study period, as opposed to 50 reported by Rehn and 70 reported by Reed. They both reported Ovenbirds and Wood Thrushes, woodland birds that were not seen in the early successional habitats of the recent study. Tables 5-1 and 5-2 (p. 5-16) show species seen by Rehn and Reed, respectively, that were not seen in the current study and Table 5-3 shows the species observed recently that were not reported by Rehn or Reed.

When Rehn conducted his survey (1900-1903), he visited several nearby

---

<sup>1</sup> Rehn, J.A.G. 1903. Notes on the Summer Birds of Lehigh Gap Pennsylvania. *Cassinia* 7(1): 11-16.

<sup>2</sup> Reed, B.P. 1984. An Eighty Year Comparison of Bird Species Utilization at Lehigh Gap, Pennsylvania. Independent research problem, East Stroudsburg State College, East Stroudsburg, PA. 24 pp.

---

<sup>3</sup> Peterson, R.T. *A Field Guide to the Birds of Eastern and Central North America*. Houghton Mifflin, 2002.

farms. Here, he found species such as Eastern Meadowlark (*Sturnella magna*) and Northern Bobwhite (*Colinus virginianus*). When this habitat was altered, both of these species disappeared from the area. Rehn also conducted his study before the effects of DDT on raptors. As a result, Peregrine Falcons (*Falco peregrinus*) were more common than they are now, and they nested in the cliffs of Devil's Pulpit. As seen in Table 5-1, Rehn had also seen species that are unusual today during the breeding season such as Savannah Sparrow (*Passerculus sandwichensis*) and Purple Martin (*Progne subis*).

Rehn reported that the predominant trees of the forests were Eastern Hemlock and American Chestnut. Since Rehn's study, most American Chestnut have been killed by Chestnut Blight (caused by *Endothia parasitica*) brought in with Chinese Chestnuts in 1904. Hemlocks have also been attacked by an insect called Hemlock Woolly Adelgid (*Adelges tsugae*), that was brought to the United States in 1954.

Air pollution, primarily sulfur-based acid deposition from zinc smelting from 1898 to 1980 killed off all of the vegetation on the Kittatinny Ridge near Palmerton. Deposition of heavy metals (zinc, lead, and cadmium) prevented re-growth and led to the demise of soil microbes. This ecological damage took place between the studies of Rehn and Reed, so in the 1980's when Reed conducted his bird survey, the area was probably barren along the slopes of the ridge, but some trees may have begun to grow back along the Lehigh River, creating brush habitat for several bird species (Table 5-2). Yellow-breasted Chats (*Icteria virens*), which prefer

brushy habitat, are not found in the Lehigh Gap anymore, possibly because the habitat has changed along the river as the trees have grown much taller. Reed did not see some common birds such as Song Sparrow (*Melospiza melodia*) probably a result of the habitat destruction, but he did see birds such as Hooded Warblers (*Wilsonia citrina*) which are uncommon today. During the time of Reed's survey, the reported predominant tree in the forested area was Chestnut Oak (*Quercus montana*); only a few American Chestnut shoots remained.



By the time of Husic's study period in 2006 and 2007, sections of the mountainside had been planted with warm-season grasses, creating the beginnings of grassland and providing new habitat for birds. Gray and sweet birch, sassafras, and species of aspen had begun to repopulate the area on the mountainside along the west side of the Lehigh Gap that was not directly seeded but may have benefited from some of the lime applications and other soil amendments spread in the nearby areas of grass seeding. The birches—which are both young and stunted (probably from stress of poor soil, the uptake of the heavy metals, and dry conditions



since there is little organic matter to hold soil moisture)—have created an unusual habitat, ideal for species such as Prairie Warbler (*Dendroica discolor*) and Indigo Bunting (*Passerina cyanea*). Breeding Prairie Warblers are difficult to find elsewhere in the region.



**Indigo Bunting**

Similar to the time of Reed, the predominant tree is Chestnut Oak, but now, other oaks, maples, sassafras, black gum, and birches are populating the area.



The area that was seeded is starting to attract some grassland species, especially during migration and in winter. Grassland species that have been found include Savannah (*Passerculus sandwichensis*), Grasshopper (*Ammodramus*

*savannarum*), and Vesper Sparrow (*Pooectes gramineus*), and in the winter, a single sighting of a Snow Bunting (*Plectrophenax nivalis*). Perhaps most exciting was the confirmed breeding of Blue Grosbeaks (*Passerina caerulea*; confirmed breeding in 2008, probable in 2009 and 2010). This represents the first documented report of breeding of this species in Carbon County. It should be noted that there has been an increased incidence of sightings and breeding of Blue Grosbeaks in Lehigh and Northampton counties. This is a species that is susceptible to decreasing open space and the conversion of farmland to housing and industrial developments.

Many of the species that were not seen by Rehn or Reed are water birds, or birds that live near the water (Table 5-3). Previously, the river had been dramatically affected by sewage from towns upstream, acid mine drainage, coal dust from shipping coal on the river, and effluent from the zinc smelting industry and tanneries. Even though Rehn's study was done early in the 1900s, the some of the sources of pollution in the river were likely already present.



**Red-tailed Hawk**

**Table 5-1. Species reported by Rehn (Rehn 1903), not seen by Husic<sup>4</sup>**

Current proper name in parentheses

---

Black-crowned Night Heron (Black-crowned Night-Heron)  
Quail (Northern Bobwhite)  
Meadow-lark (Eastern Meadowlark)  
Savanna Sparrow (Savannah Sparrow)  
Purple Martin  
Oven-bird (Ovenbird)  
Yellow-breasted Chat  
Wood Thrush

Purple Finch<sup>† ‡</sup>

\*nest and feed near water

†nest and feed in forests

‡only seen once

**Table 5-2. Species Reported by Reed (Reed 1984) not seen by Husic<sup>4</sup>**

Current proper name in parentheses

---

Ring-billed Gull  
Willow Flycatcher  
Least Flycatcher  
Wood Thrush  
Ovenbird  
Hooded Warbler  
White-throated Sparrow

**Table 5-3. Species reported by Husic that were not reported by Reed or Rehn<sup>4</sup>**

---

Double-crested Cormorant\*  
Great Blue Heron\*  
Wood Duck\*  
Green Heron\* ‡  
Sharp-shinned Hawk†  
Bald Eagle\*  
Warbling Vireo\*  
Common Raven  
White-breasted Nuthatch†  
Chestnut-sided Warbler†  
Magnolia Warbler†  
Prairie Warbler  
Dark-eyed Junco  
Orchard Oriole‡

---

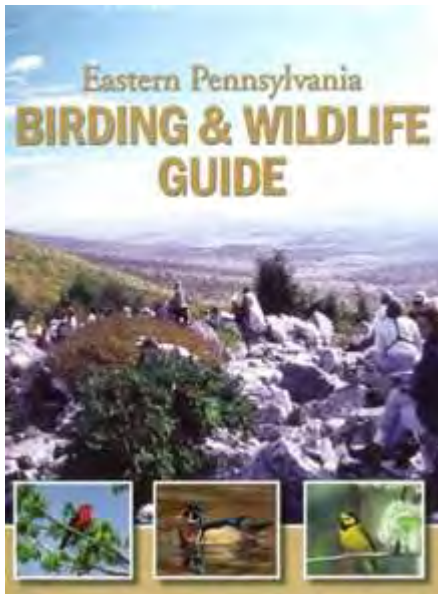
<sup>4</sup> Updated from Corey Husic's original paper of 2007.





**Common Nighthawk**

The value of the Lehigh Gap Wildlife Refuge as an important birding destination site was acknowledged by inclusion of the LGNC in the Eastern Pennsylvania Birding and Wildlife Guide published in 2009. In the State of the Kittatinny Ridge report published by Pennsylvania Audubon in 2010, the LGNC is included as a case study of “Conservation in Action”.<sup>5</sup>

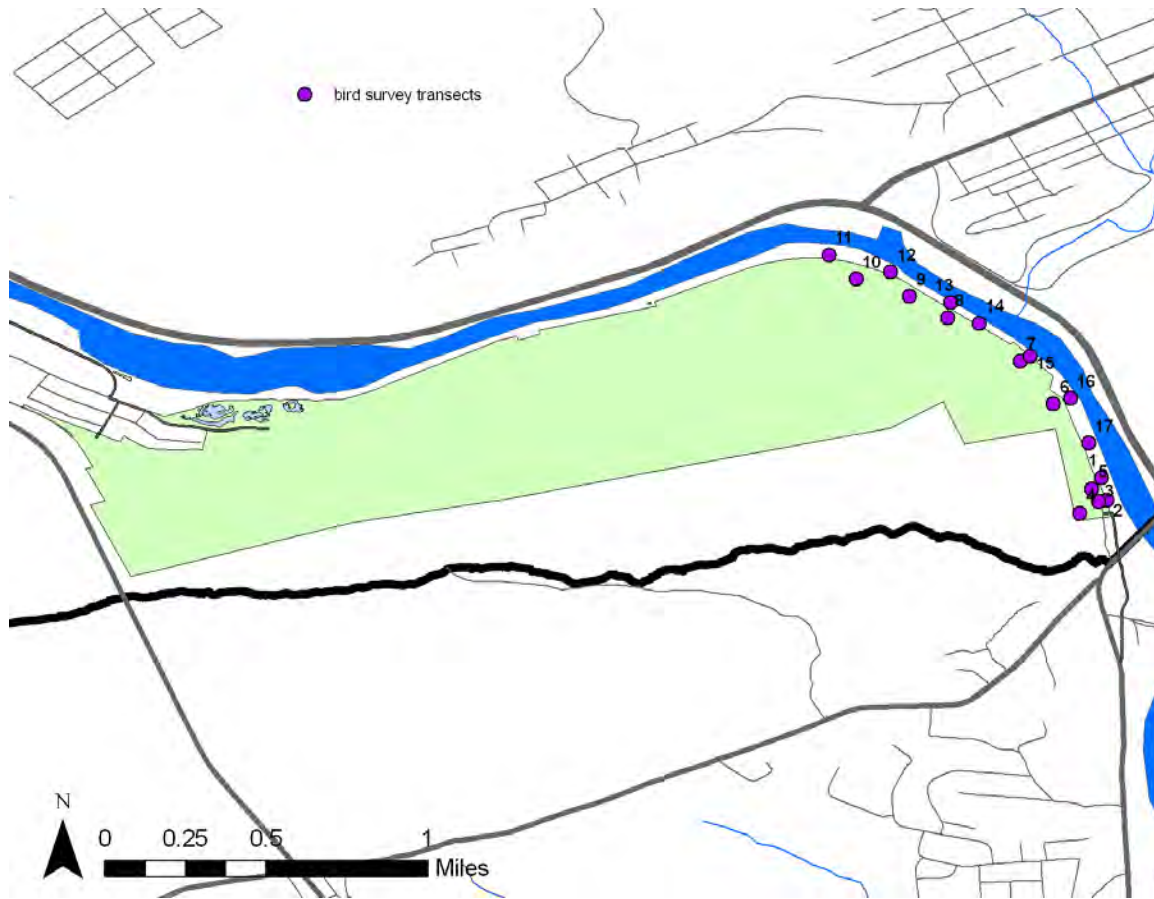


Birders and naturalists hope that birds such as Savannah, Grasshopper, and Vesper Sparrows, Bobolinks (*Dolichonyx oryzivorus*), Eastern Meadowlarks (*Sturnella magna*), and Horned Larks (*Eremophila alpestris*) will breed in the newly created grasslands. Other birds such as Lapland Longspurs (*Calcarius lapponicus*) and Northern Shrike (*Lanius excubitor*) would be important indicators of the restored habitat during the winter. It will be important to continue this study (and other bird surveys throughout the Refuge property) in subsequent years for many years as it will take time for some species to come back and because the area is constantly undergoing change by succession and invasions by alien species.



**Common Merganser**

<sup>5</sup> Report can be found at: <http://pa.audubon.org/PDFs/FinalKittatinnyReport.pdf>; case study is on page 11.



**Area and Transects Within the LGWR Where Bird Surveys Were Conducted (2006-2009)**

## *Chapter 6*

# *Biota of the Lehigh Gap Wildlife Refuge – Insects*





# *LGWR Biota – Insects*

## **Survey of the Insects at the LGWR**

Part I of the Lehigh Gap Wildlife Refuge Ecological Assessment contained the results of insect surveys performed with light traps in 2006.<sup>1</sup> The vast majority of the specimens collected were moths (Lepidoptera).



**Light Traps**



**Malaise trap**

In order to obtain a more complete picture of the insects of the Refuge, several other trapping methods were used for Part II of the assessment. As well as trapping, visual surveys were also conducted for diurnal species of

butterflies (Lepidoptera) and dragonflies and damselflies (Odonata).

### **General Insect Trapping Methods:**

Malaise traps (tent-like net traps shown in the photo below) are used to collect flying insects. The traps funnel insects into a collecting bottle filled with alcohol. The net trap is set up and checked periodically (every 1-2 weeks). The alcohol kills and preserves the collected specimens.



Pitfall traps (see image on the next page) are used to collect crawling insects. These are homemade devices with a 1"x4"x24" board standing on edge that serves as a barrier to crawling insects. At each end of the board, a one-pint plastic deli container is buried and filled with Sierra brand antifreeze, which is nontoxic to vertebrates. A rain shield is affixed to the top edge of the board to prevent dilution of the antifreeze. The antifreeze kills and preserves the insects. Collecting the specimens was

<sup>1</sup> See Appendix D in <http://lgnc.org/wp/wp-content/uploads/2009/06/lgnc-ecological-assessment.pdf>.

accomplished by straining the insects from the antifreeze and storing them in alcohol in plastic bags. The antifreeze was subsequently re-used in other traps.



**Pitfall trap**

Malaise and pitfall traps were deployed from May through August 2008 at the same three sampling locations on the Refuge as the light traps in 2006. These sites included the bottomland wetland in the Kittatinny Ponds area; a mid-slope hollow with scattered trees amid the re-vegetated grassland area; and the pitch pine-hairgrass savanna near the crest of the ridge. Traps were set and insects were collected weekly when possible, and biweekly on a few occasions. Two malaise traps were destroyed during the sampling period. Samples were strained from the trapping medium and stored in a freezer until being transported to Dr. John Rawlins at the Carnegie Museum of Natural History in Pittsburgh for identification and cataloging.

### **Insect Trapping Results:**

The complete results of the 2008 malaise and pitfall trapping surveys (and a more detailed description of

the survey methods) are reported in Appendix C-1. Specimens from 13 insect orders representing over 100 families were collected in 2008. There were 33 Carabidae species that were new records for Carbon County; trapping for Part I of the assessment in 2006 yielded an additional 54 new county records. In the survey there were new state records as well.

One specimen of *Niphonyx segregata*, a Lepidoptera, was found in 2006 but not identified and confirmed until this report. This represents the northernmost record for this northeast Asian noctuid which might be a potentially new invasive insect in the U.S.

The report contains a complete listing of the species identified from the 2008 traps as well as some phenology data for these species. Given the importance of phenology data for monitoring impacts of climate change, the information in this part of the database could be extremely valuable for future monitoring at the LGWR and other regions along the Kittatinny Ridge.

### **Reference:**

Malaise Traps. Mississippi Entomological Museum. <http://mississippientomologicalmuseum.org.msstate.edu/collectingpreparation.methods/Malaise.traps.htm>

### **Hymenoptera (Native Bee studies):**

In addition to generalized insect trapping, the LGNC has been trapping bees since 2007. The survey at the LGWR is a part of a larger collaboration of scientist and naturalists surveying the native bee flora east of the Mississippi. Sam Droege, U.S. Geological Survey (USGS), is coordinating the project and providing support for data entry and storage, identification, and sample distribution for reference and related studies (i.e. DNA comparisons between species). The primary goal is to determine what species exist on the east coast, relative to studies done in the early 1900s, and what new species might be found, both native and exotic. As the survey continues over years, the population shifts will be documented. Transects have been placed in diverse habitats for species comparisons.

This study has national and international significance given the widespread occurrence of the Colony Collapse Disorder which is dramatically reducing the populations of honey bees that are essential for pollination of a number of crops. If the honey bee disappeared, crop plants would need to rely on native bees for pollination. This study helps scientists determine the presence, abundance, and range of these native bee species. For sites such as the LGWR, the abundance of species and individuals will provide a high quality measure of the effectiveness of the reclamation of damaged habitat. Additional studies may be done on the biology of specific species, including plants that they pollinate.

Participants in the project include the Coordinator for Northeast Pennsylvania and bee identifier, Dr. Anita M. Collins, Dept. Entomology, The Pennsylvania State University; site coordinator; Dan Kunkle; members of the LGNC Naturalists Club and other volunteers who comprise the sampling crew and help to collect, wash and pin the bees; and the national coordinator, Sam Droege.



#### **Collecting specimens from bee traps**

Bees are collected using a standard bowl trapping protocol in which a series of fifteen 3.2oz plastic bowls are distributed five meters apart, alternating blue, yellow and white bowls. This constitutes one transect line. These colors (paint specific) have been determined to be most attractive to foraging bees. A small amount of soapy water is placed in each bowl to drown and hold the bees. After 8 to 48 hours the bees are collected and strained, placed in alcohol, and stored in a refrigerator. Samples are later washed, dried and pinned for identification. Data on date, location, collector, GPS coordinates, species,



weather and habitat are entered into a national database (USGS). From this information, maps of specific transects can be generated. A more detailed description of the collection method written by Sam Droege can be found in Appendix C-2.



**Washing the bees at the Osprey House**

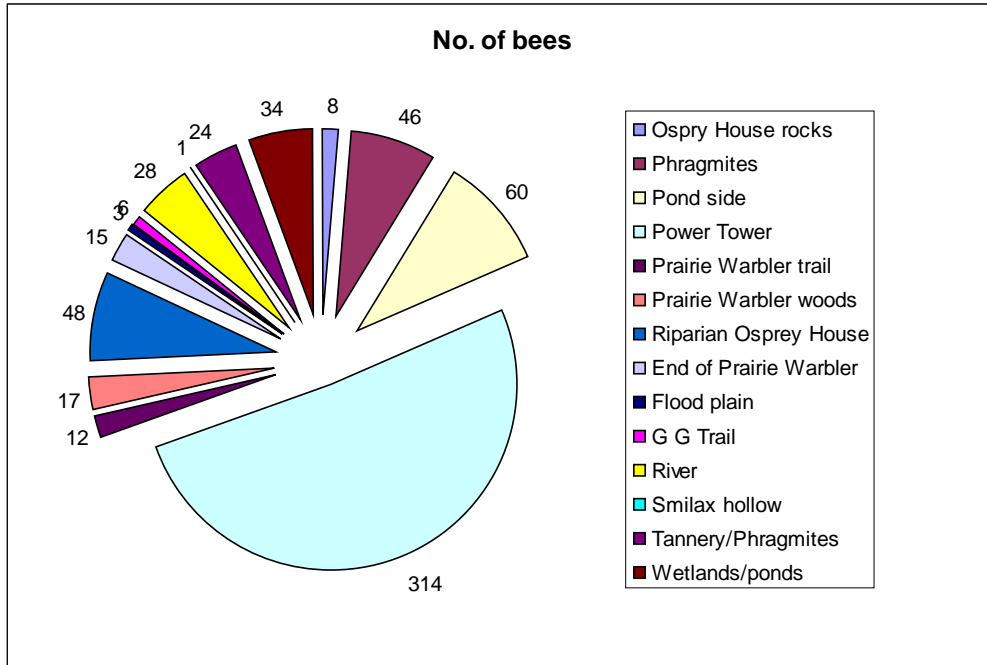
Identification of samples collected in 2007 (April 28<sup>th</sup> and June 14<sup>th</sup> surveys) and 2008 (survey dates from May 3<sup>rd</sup> to September 17<sup>th</sup>) is still ongoing, but some partial data and a preliminary species list are included in this report. Bees were found in all eight transects placed in the vicinity of Osprey House. Bees from additional transects throughout the Refuge have also been collected. Thirty-four bee species from 14 genera have been identified so far. A preliminary list of bee species identified to date (from the 2007 collection) is included as Appendix C-3.



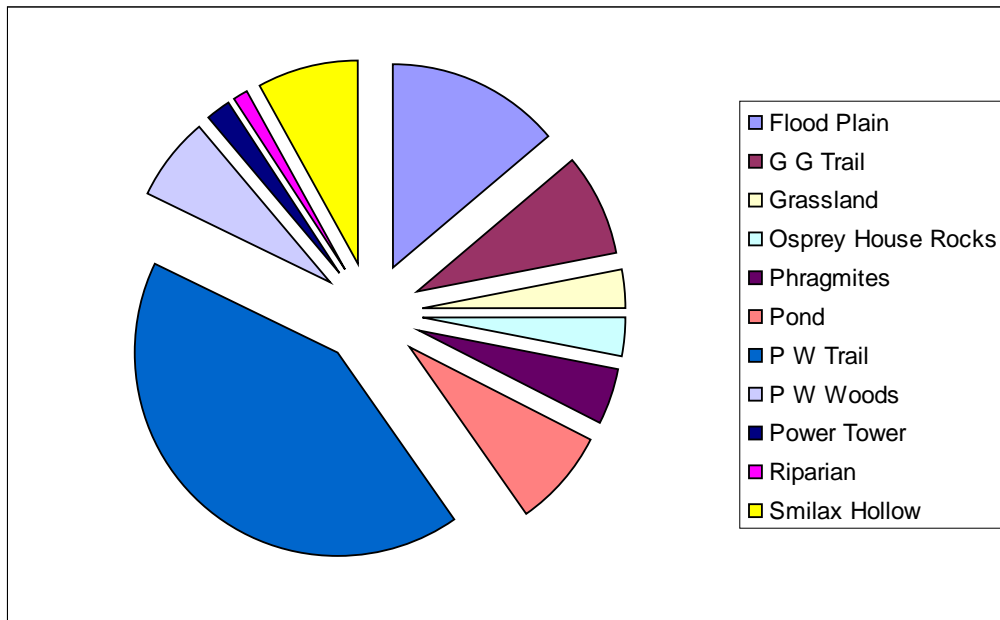
**Sorting through the collected specimens**



**Preliminary identification and pinning of specimens.** Dr. Collins is on the left. Others in the photo are members of the LGNC Naturalists Club.



Number of bees by site - 2007



Number of bees by site - 2008

The above pie charts give a sense of the numbers of bees by site in various locations on the Refuge. It is important to note that not all sites were sampled an equal number of

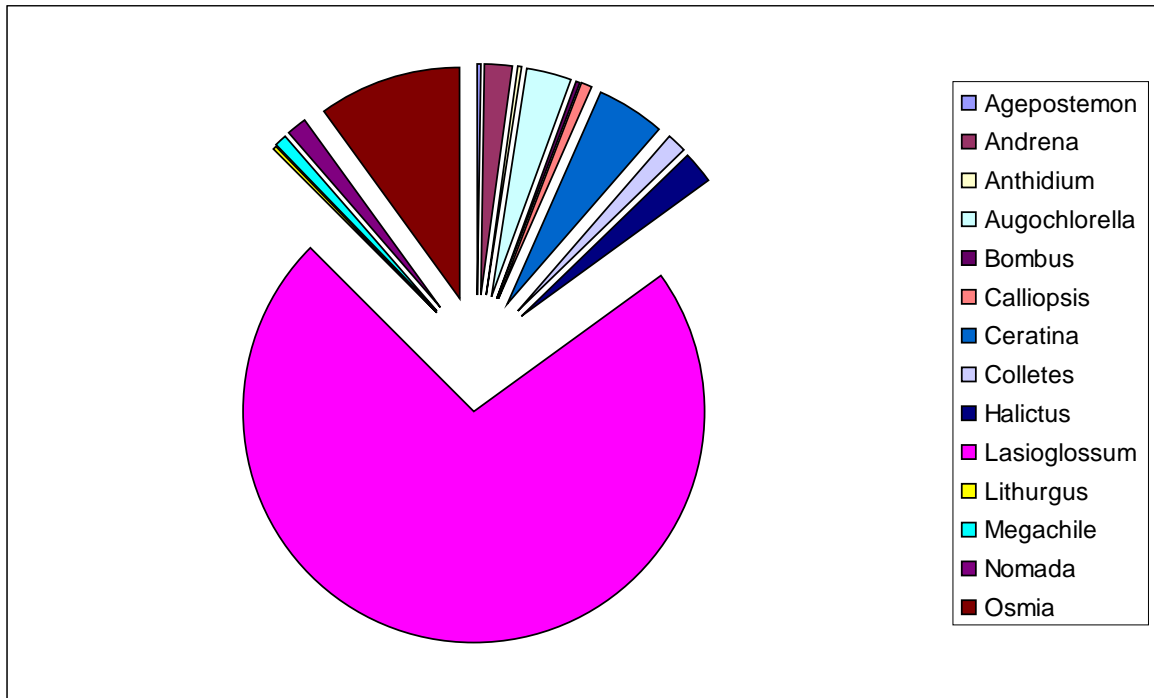
times. However, in reviewing the raw data, on a given date, the areas with the highest numbers of bees in pie chart also typically had the highest number of bees in a given survey.

In general, the highest numbers of bees were trapped in the month of May and the lowest numbers were from traps set in August and September. Exceptions to this were along the GG Trail (a woodland trail on west end of Refuge), in the phragmites transect between the road to LGNC and Lehigh River just to the south of the Osprey House, and the grassland areas. Consistent numbers of bees were trapped in these areas throughout the season.



*Megachile sp.*

From 2007, a total of 306 specimens representing 14 genera and 31 identified to the species level were captured (see figure below). That diversity was concentrated in the *Lasioglossum* genus represented by 222 of the specimens of 15 different species.



Number of bee specimens by genus - 2007

One of the most interesting findings, and one with possibly the most important consequences, was the trapping of a specimen of an exotic carpenter bee, *Lithurgus chrysurus*, near the Osprey House and Tannery building at LGNC. This is a Mediterranean carpenter bee last documented in Phillipsburg, New Jersey in the early 1970s; this bee

species destroyed a porch and was thought to have been eradicated. The discovery of this species at the LGWR initiated a search for more specimens by USGS and the Pennsylvania Department of Agriculture. More specimens were found, but the species is not currently known to be causing economic damage to structures.



*Halictus* sp.

**Short bibliography of relevant papers for the bee study:**

Campbell, J. W., and J. L. Hanula. 2007. Efficiency of Malaise traps and colored pan traps for collecting flower visiting insects from three forested ecosystems. *Journal of Insect Conservation* 11:399-408.

Cane, J. H., R. L. Minckley and L. J. Kervin. 2000. Sampling bees (Hymenoptera: Apiformes) for pollinator community studies: pitfalls of pan-trapping. *Journal of Kansas Entomological Society* 73:225-231.

Cockerell, T.D.A. 1903. North American Bees of the Genus *Nomada*, *Proceedings of the Academy of Natural Sciences of Philadelphia*, Vol. LV, Edward J. Nolan, ed.

Giles, V. and J. S. Ascher. 2006. A survey of the bees of the Black Rock Forest preserve, New York (Hymenoptera : Apoidea). *Journal of Hymenoptera Research* 15: 208-231.

Hopwood, J. L. 2008. The contribution of roadside grassland restorations to native bee conservation. *Biological Conservation* 141:2632-2640.

Leong, J. M. and R. W. Thorp. 1999. Color-coded sampling: the pan trap colour preferences of oligolectic and nonoligolectic bees associated with a vernal pool plant. *Ecological Entomology* 24:329-335.

Roulson, T. H., S. A. Smith and A. L. Brewster. 2007. A comparison of pan trap and intensive net sampling techniques for documenting a bee (Hymenoptera: Apiformes) fauna. *Journal of Kansas Entomological Society* 80:179-181.

Toler, T. R., E. W. Evans, and V. J. Tepedino. 2005. Pan-trapping for bees (Hymenoptera: Apiformes) in Utah's West Desert: The importance of color diversity. *Pan-Pacific Entomologist* 81:103-113.

U.S. Geological Survey, National Biological Information Infrastructure. 2009. The Very Handy Manual: How to Catch and Identify Bees and Manage a Collection. <http://bio2.elmira.edu/fieldbio/beemanual.pdf>

U.S. Geological Survey, National Biological Information Infrastructure Online Bee Identification Guide. <http://www.discoverlife.org/20/q?search=Apoidea>

U.S. Geological Survey, National Biological Information Infrastructure. 2008. What Kind of Bee Is That? Online Identification of Native Bees. [http://www.nbii.gov/images/uploaded/8496\\_1205443948002\\_Bee\\_ID\\_Guide\\_fact\\_sheet\\_1-08.pdf](http://www.nbii.gov/images/uploaded/8496_1205443948002_Bee_ID_Guide_fact_sheet_1-08.pdf)

## Wasps

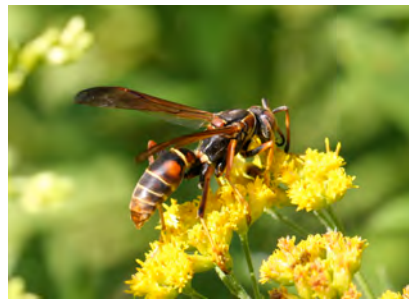
During late summer of 2009, Sam Droege of the USGS conducted a pilot study of wasp trapping techniques in the eastern United States. At the LGWR, three traps were set, which collected a total of 219 wasps of six species. The traps were 500mL plastic water bottles with the labels peeled off filled with apple juice.



**Wasp trap**

The three traps were set in different habitats in the southern section of the LGWR. The first trap was placed in a serviceberry tree in the Habitat Garden at the Osprey House. The trap was placed very close to several fall-blooming plants, which attract

numerous species of wasps. The second trap was located in the riparian zone, which consists mainly of Red Maple and River Birch. The third trap was placed in the oak forest above the Prairie Warbler Trail. The three traps were put out on August 18, 2009 and left out for three weeks. The samples were then cleaned and placed in plastic bags with alcohol and sent to Sam Droege for identification.



***Polistes fuscatus***

A list of the species collected is included in the table below. S. Droege indicated that, as of October 2009, the *V. vidua* species trapped at the LGWR were the first that had been reported in over 100 traps in the USGS study. He also commented on the relatively high number of yellow jackets captured at the Refuge.



**Results of 2009 Wasp Trap Survey at the LGWR**

| <b>Trap:</b>                   | <b>Trap 1<br/>(Habitat<br/>Garden)</b> | <b>Trap 2<br/>(Riparian)</b> | <b>Trap 3<br/>(Forest)</b> | <b>Total</b> |
|--------------------------------|----------------------------------------|------------------------------|----------------------------|--------------|
| <i>Vespa crabro</i>            | 1                                      | 1                            | 8                          | <b>10</b>    |
| <i>Vespula maculifrons</i>     | 11                                     | 29                           | 26                         | <b>66</b>    |
| <i>Vespula flavopilosa</i>     | 15                                     | 8                            | 80                         | <b>103</b>   |
| <i>Vespula vidua</i>           | 0                                      | 0                            | 3                          | <b>3</b>     |
| <i>Dolichovespula maculata</i> | 12                                     | 12                           | 12                         | <b>36</b>    |
| <i>Polistes fuscatus</i>       | 1                                      | 0                            | 0                          | <b>1</b>     |
| <b>Total</b>                   | <b>40</b>                              | <b>50</b>                    | <b>129</b>                 | <b>219</b>   |

## Diurnal Lepidoptera and Odonata Surveys

Visual surveys for diurnal Lepidoptera (butterflies and skippers) and Odonata (dragonflies and damselflies) were conducted at the Refuge starting in 2009. The purpose of these observations was to compile a species list for these insect groups to supplement the trapping that was conducted. Appendix C-4 records the species list compilation for these two orders.



**Gray Hairstreak**

Seventeen damselfly, seventeen dragonfly, and forty-six butterfly species have been recorded at the LGWR. This list is considered preliminary; additional surveys, some planned in conjunction with the Entomological Society of PA, will be conducted in the future.



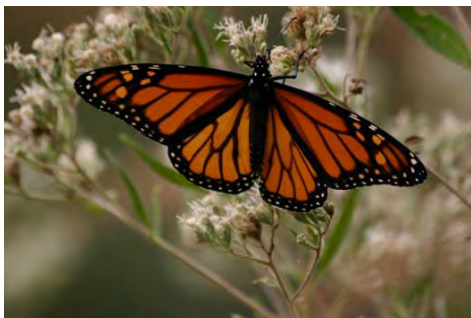
**Powdered Dancer**

Of the butterflies observed at LGWR, several are important indicators of the health of the restored grassland. Several species of skippers (Hesperiidae), including Swarthy Skipper (*Nastra lherminier*) and Little Glassywing (*Pompeius verna*), require the grasses in the re-vegetated hillside to survive. As well as being an important place for grassland butterflies, the Refuge holds large populations of locally uncommon butterfly species including Common Roadside-Skipper (*Amblyscirtes vialis*) and Milbert's Tortoiseshells (*Aglais milberti*). Occasionally during the summer months, many of the Common Roadside-Skippers can be found on the old railroad beds along the river. During the late fall months, Milbert's Tortoiseshells fill the autumn flowers. It is not uncommon to find twenty or more of these spectacular butterflies along the railroad bed and in the gardens, even after most other butterfly species have disappeared due to the cold weather.



**Milbert's Tortoiseshell**

The Lehigh Gap Naturalist Club has also been trapping and tagging Monarch butterflies (*Danaus plexippus*) through the University of Kansas's Monarch Watch program for the past three years. During his bird surveys, Corey Husic recorded numbers of migrating monarchs. A high count of 1028 monarchs on September 2, 2007 highlights the importance of Lehigh Gap as part of the migration corridor for these butterflies, just as the Kittatinny Ridge is a leading line for raptor migration. The Refuge seems to serve as an important stopover site for resting and feeding, formerly almost exclusively on butterfly bush (*Buddleja davidii*), which is being controlled. Increasingly, the monarchs are feeding on late eupatorium or throughwort (*Eupatorium serotinum*), white-snakeroot (*Ageratina altissima*), and other species flowering in early autumn. Because of this, the Refuge is careful not to eradicate the entire population of butterfly bush until native nectar plants are well-established.



As well as the monarch research, several programs have been conducted at the Lehigh Gap highlighting the importance of monarchs and their migration. These

programs have ranged from simple introductions to the butterfly and its natural history to monarch tagging programs, where the public captures and tags the Monarchs during the butterfly's migration to Mexico during the fall months.

### Reference:

Migration and Tagging, Monarch Watch.

<http://monarchwatch.org/tagmig/index.htm>.



### The Regal Fritillary

In July 2009, several researchers and staff of the Lehigh Gap Nature Center visited Fort Indiantown Gap (FIG), Pennsylvania to learn about conservation efforts of the endangered Regal Fritillary (*Speyeria idalia*). The natural range of the Regal Fritillary used to cover most of eastern and central United States until humans began to destroy the grassland habitats required by the butterflies. Today, these butterflies are extremely rare in eastern United States, but FIG, with its extensive grassland habitat, has the only remaining breeding population in the East. Biologists at FIG are interested

in cultivating relationships with owners of potential Regal Fritillary introduction sites.

Regal Fritillaries require warm-season grasslands with key nectar and larval food plants to survive. This is of interest to the LGWR, as a grassland with native nectar sources is already being established. To make the site suitable for Regal Fritillaries, the nature center would need to establish the larval food plant, arrow-leaved (*Viola sagittata*) and bird's-foot (*V. pedata*) violets in the grassland.



**Regal Fritillary**

Arrow-leaved violet (*Viola sagittata*) grows naturally at the top of the ridge, and a few trial bird's-foot violets have been planted in the deer-exlosures at the Refuge to determine whether or not they can tolerate the metals in the soil. In November 2009, three members of the FIG team visited the Refuge. They determined that the site could potentially become desirable habitat for Regal Fritillaries. Since regals use Little Bluestem (*Schizachyrium scoparium*) grass clumps for pupating, the biologists were especially interested in finding that species and they did find scattered clumps that should be sufficient.

The FIG biologists identified two major challenges to the site for regal introduction. One is maintaining the area as grassland by halting the spread of woody plants into the grassland area. The second is establishing nectar and food plants for the butterflies.

Gray birch (*Betula populifolia*), aspens (*Populus sp.*), and invasive butterfly bush (*Buddleja davidii*) and tree-of-heaven (*Ailanthus altissima*) are all colonizing the site and will lead to diminishing the amount of grassland available if ecological succession is not halted. In this region along the Kittatinny Ridge, forest is the usual outcome of succession. In order to keep the site as a grassland, a management plan must be put into place that resets the clock on succession continually. One component of a successful grassland management plan is fire, and prescribed burns could be used to help with the management of the grasslands at LGWR. The team from FIG could be a valuable resource to help us develop and implement management using fire.

The second challenge is already beginning to be addressed with the grassland enhancement and deer plot study area (see Chapter 8). Experimental planting of nine native flowering forbs that produce nectar, pollen and seed that is valuable to wildlife was conducted in 2009. In addition, we have planted several dozen native field thistles (*Cirsium discolor*) provided by FIG in 2009. We have also been spreading seeds of common and butterfly milkweed (*Asclepias syriaca* and *A. tuberosa*) and

several other species to enhance the grassland. Along with other species coming in on their own (e.g. *Eupatorium serotinum* and goldenrods, *Solidago sp.*), the FIG staff members felt that the nectar part of that equation is being taken care of; however, we still need to figure out how to establish essential violets that serve as the larval food plants of the fritillaries.

During the visit to the Refuge, the FIG staff mentioned that they are removing Big Bluestem (*Andropogon gerardii*) because of its tendency to be sod forming in their location, while Regal Fritillary needs clump grasses such as Little Bluestem. D. Kunkle expressed a concern that the LGNC cannot do “single species management” here just to host Regal Fritillaries, but that a goal is to maximize native biodiversity at the Refuge. The FIG researchers understood and agreed that single species management is not the proper approach at the LGWR. Kunkle also assured them that no grass species could form sod here because of the rocky conditions.

The FIG staff sees our site as a place with potential. We have the necessary grass species and are establishing nectar species. If we can also establish the critical violet species, the host plant for regal larvae, and develop a management plan to maintain the grasses, LGWR could become a Regal Fritillary introduction site. A number of FIG scientists returned twice in 2010 (July 30 and September 29) to further evaluate the site as potential Regal habitat, to conduct a survey of

butterfly fauna, and to discuss control burn strategies.

**Reference:**

McNaughton, D., J. Hovis, M. Swartz, and N. Hoffman (2009) Grassland Restoration and Management Plan for the Repatriation of the Regal Fritillary Butterfly (*Speyeria idalia*), Report for Project Number 08-392, Department of Defense, Legacy Resource Management Program.



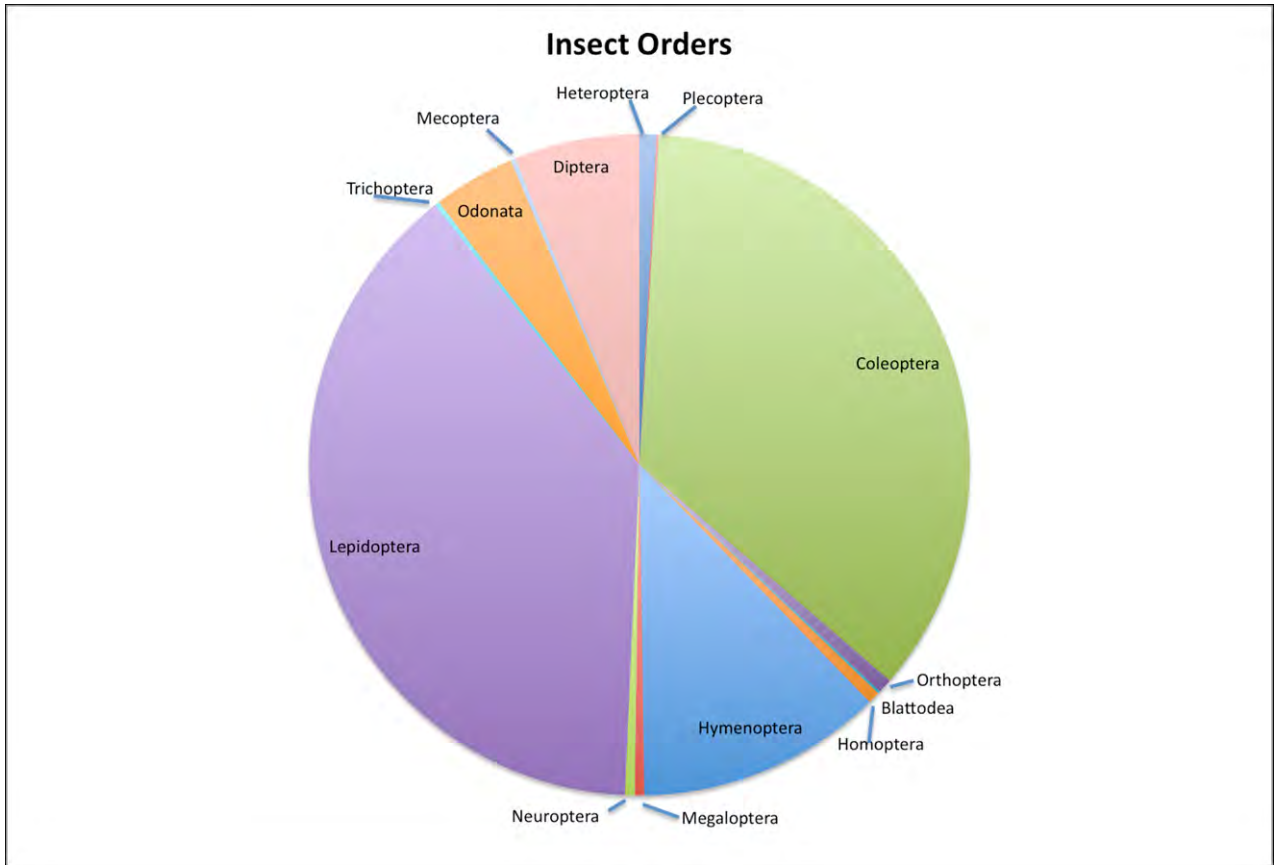
**Crossline Skipper**

**Compilation of the Insect Inventory at the LGWR**

A compilation by C. Husic of all 851 insect species observed at the Refuge through trapping and visual surveys (as of December 2010) is found in Appendix C-5. With this comprehensive database, further analysis using biotic indices should be conducted to determine the quality of the environment at the various sampling sites on the Refuge at this time and stage of restoration. In addition, the current survey data should be compared to historical records (e.g. the Cockerell bee study of 1903 referenced above and the Rehn insect collection reports from the early 1900s typically published by the Academy of the Natural Sciences of Philadelphia). The distribution of



species within insect orders is represented in the pie chart below.



**Distribution of LGWR Insect Species Identified to Date by Order**





**Widow Skimmer**

### **Macroinvertebrate Diversity Study LGWR Ponds**

The purpose of this project was to establish an inventory of the macroinvertebrate populations in three ponds on the west end of the Refuge all of which had been historically impacted by heavy metal contamination from the zinc smelters. Each of the three pond sites were sampled with 1000  $\mu\text{m}$  mesh nets. From 100 to 200 macroinvertebrates were sampled at each pond, yielding 25 to 50 different species.

Macroinvertebrates were sorted and identified to family or genus and diversity measured using the Shannon and Hilsenhoff Family Biotic Indices. The samples included algae and protozoans, but also larval stages of insects. Thus, the study (summarized in a poster in Appendix D) is mentioned here.

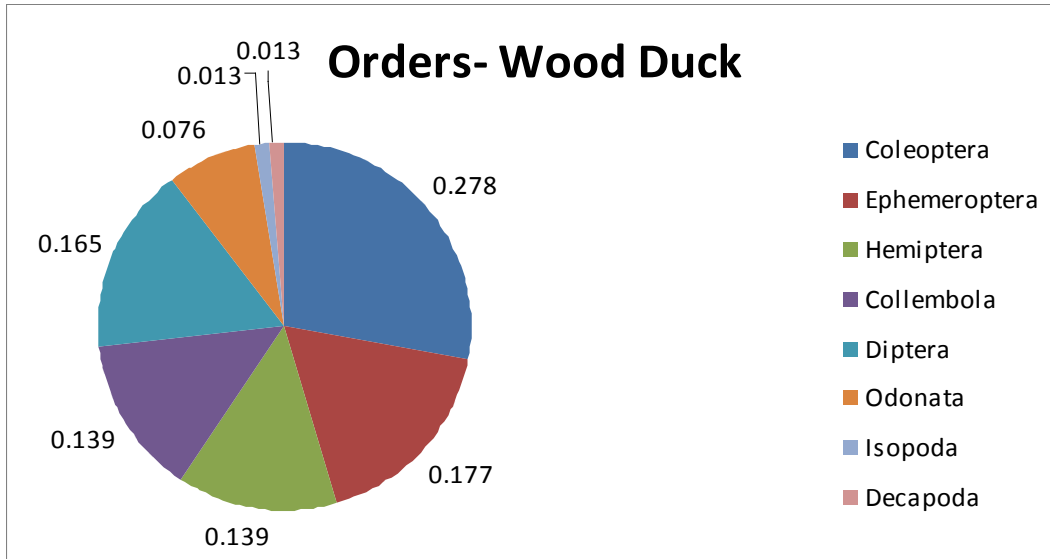
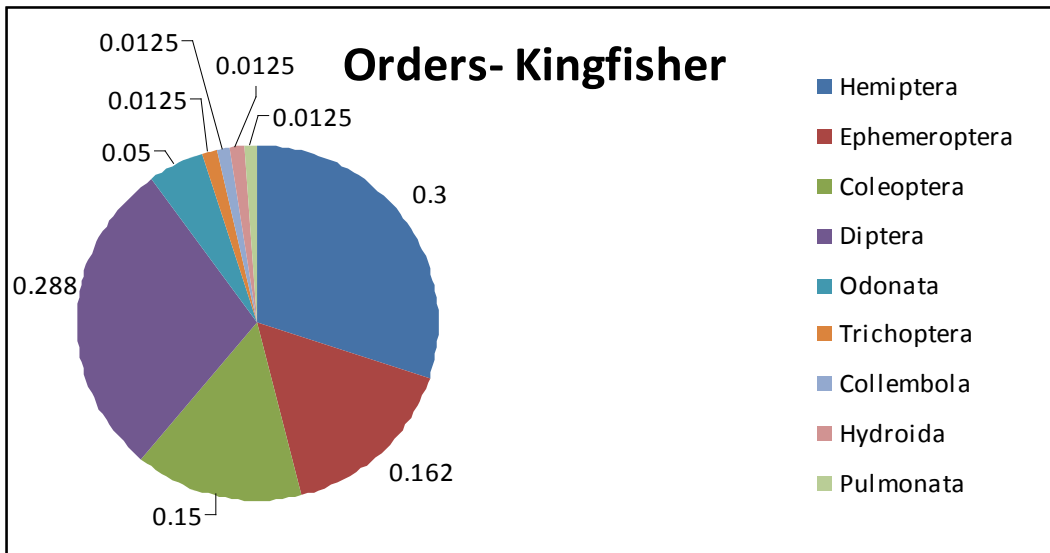
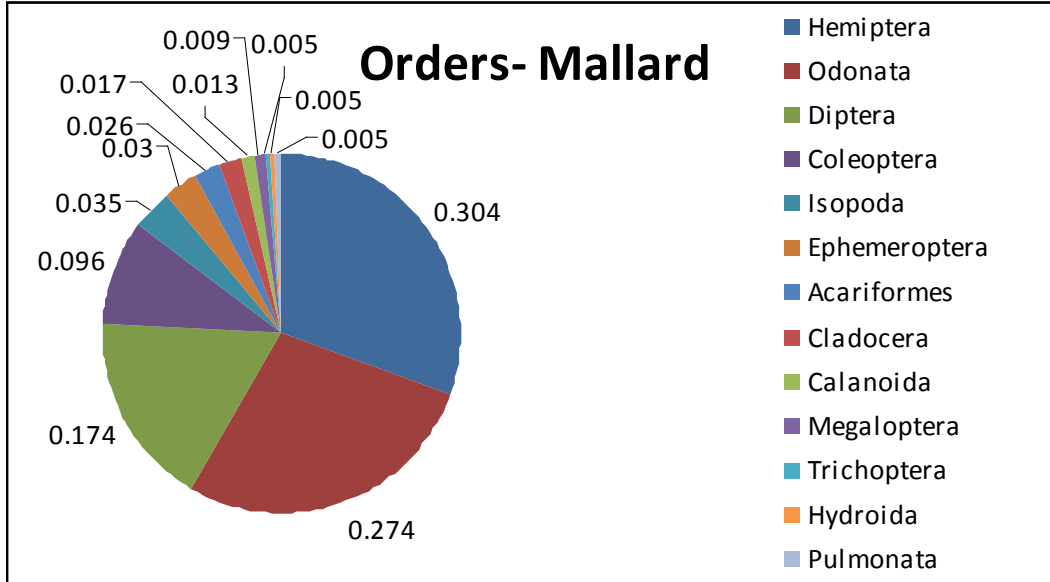


***Baetidae sp***

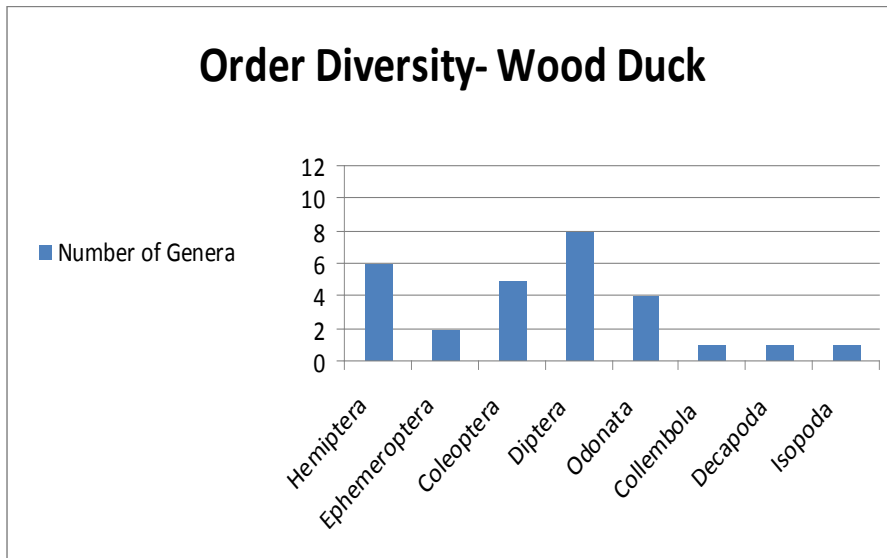
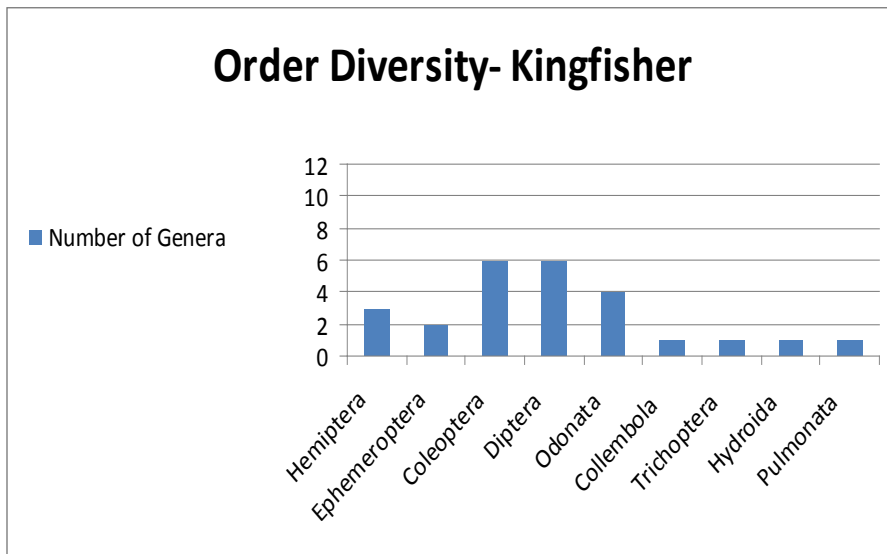
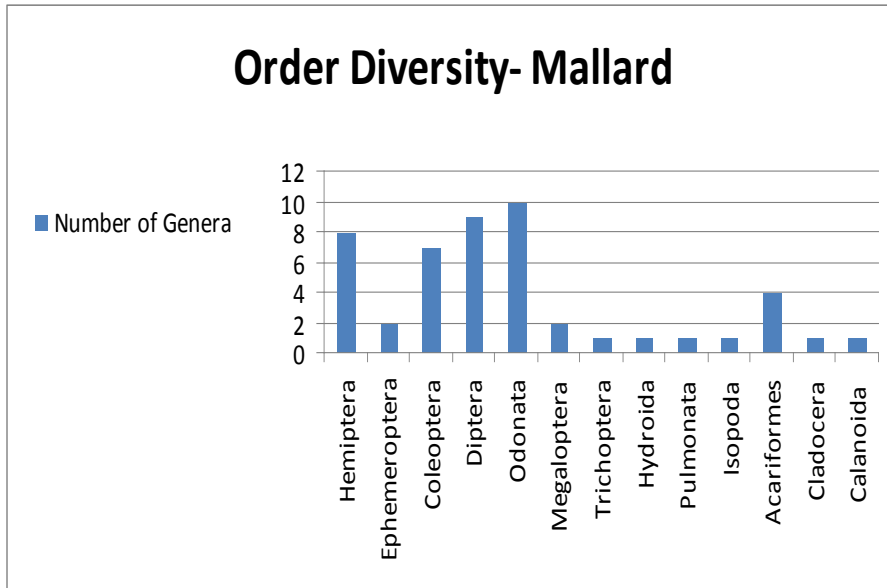
Two summary figures from this study are included on the subsequent pages.



**Percentage of Individuals (Macroinvertebrates) in Each Order for the Three LGWR ponds**

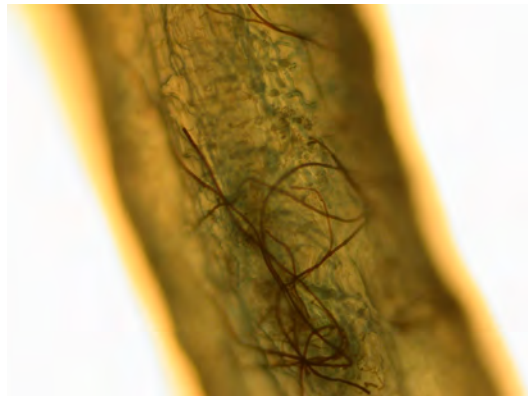


**Number of Macroinvertebrate Genera Represented in Each Order from the LGWR Ponds**



## *Chapter 7*

# *Biota of the Lehigh Gap Wildlife Refuge – Microorganisms*



**Mycorrhizae in a Plant Root**

# LGWR Biota – Microorganisms

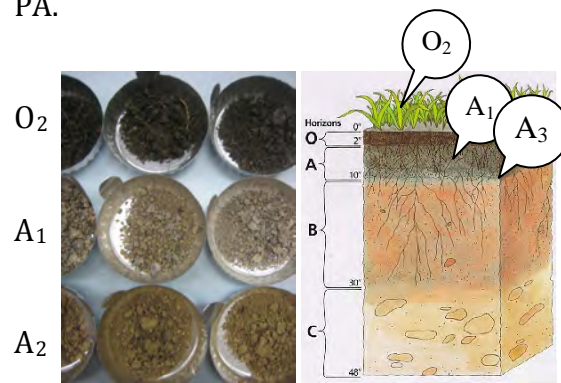
Disturbance of native plant communities, such as what occurred from decades of zinc smelting, is often followed by degradation of both physical and biological soil properties, soil structure, nutrient availability and organic matter. At the LGWR, severe erosion took place leaving behind nothing except mineral soil and bare rock. This damage, along with the loss of vegetation, was obvious. However, the damage to the soil microbial communities is also important to consider. High concentrations of heavy metals have shown adverse effects on soil microbial populations, so it is of interest to study various microorganism communities at the LGWR and throughout the larger Palmerton Superfund site area.

## Soil Bacteria

A survey of soil microflora was conducted 32 years ago by Marilyn J. Jordan (formerly known as M.J. Buchauer) and Mary Lechevalier (1975) of Rutgers University's Waksman Institute of Microbiology. They concluded that the heaviest of zinc-contaminated soils experienced the greatest loss in total numbers of bacteria, fungi and actinomycetes. In 2007, Armando Villafañe, Jr. and Dr. Frank Kuserk of Moravian College proposed a study to determine what changes microbial populations and communities have undergone since the 1975 study. A full write-up of this study entitled "**Current State of the Soil Microflora at the Palmerton, Pa Superfund Site**" is included as

Appendix E-1. This research was accepted for presentation at the 2008 National Conferences on Undergraduate Research held at Salisbury University in Maryland. Villafañe was able to communicate with M. Jordan to determine the sampling sites and methods from the earlier study. Dr. Hank Edenborn of the National Technology Energy Laboratory of the U.S. Department of Energy in Pittsburgh performed the soil metal analyses.

In the previous study Jordan and Lechevalier recorded up to 129,000 ppm of zinc (Zn), 1800 ppm of cadmium (Cd), 2150 ppm of copper (Cu) and 1900 ppm of lead (Pb) in the O<sub>2</sub> soil horizon of the most affected site. Current (2007) metal concentration in the O<sub>2</sub> horizon at this site have decreased significantly with measurements of 4348 ppm of Zn, 68 ppm of Cd, 177 ppm of Cu and 649 ppm of Pb being recorded. Heavy metal concentrations have also significantly declined in the A<sub>1</sub>, and A<sub>3</sub> soil horizons within 2 km of the east-plant zinc (Zn) smelter in Palmerton, PA.



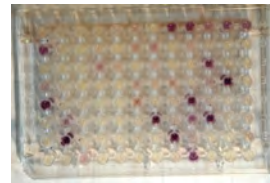
Soil Samples Collected from 3 Layers



While these metal levels are still considered higher than normal, microbial populations have demonstrated some ability to recover. When compared to the microbial population counts in 1975, total numbers in soil microflora (bacteria and fungi) populations in 2007 were notably higher, particularly in the O<sub>2</sub> horizon of the most affected sites (*S1* and *S2*). A strain of *Alcaligenes eutrophus*, a bacteria classified by its ability to demonstrate plasmid-bound resistance to Co<sup>2+</sup>, Ni<sup>2+</sup>, Zn<sup>2+</sup> and Cd<sup>2+</sup> ions, was isolated from *S1* and *S2* soils. The increase in soil microflora (bacteria and fungi) populations at *S1* and *S2* (those sites most severely impacted by smelting) over the last 32 years correlate with reduced metal contamination of these soils and confirms early stages of soil formation at these sites.

As a follow-up to the Villafane, *et al.* study, Vivian Clarke-Ruiz, under the supervision of Dr. Kuserk, conducted a study entitled ***“Evidence for Zinc Tolerance Among Bacteria of the Palmerton, PA Area”***. The entire report for this study is included as Appendix E-2. The project was selected for presentation at the 2009 National Conferences on Undergraduate Research held at the University of Wisconsin, LaCrosse and the poster that was presented is included as Appendix E-3.

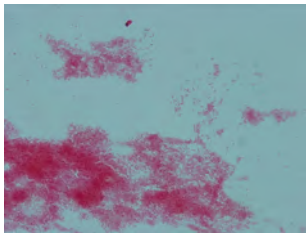
This research repeated some of the 2007 field sampling to verify that bacterial numbers at affected sites had indeed recovered from 1975 levels and looked at zinc tolerance among bacteria isolated from soils at the re-sampled sites. Bacteria isolated and identified from soils at all three sites were found to be common soil bacteria, including species from the genera *Staphylococcus*, *Arthrobacter*, *Pseudomonas* and *Rahnella*.



A third study from the Kuserk lab at Moravian College was done by Nicole Sarson to further identify bacteria in the metal contaminated soils. This study entitled ***“Identification of Bacteria found in Metal Contaminated Soils near Palmerton, PA”*** is included as Appendix E-4. In the previous studies, students isolated twenty bacteria samples from contaminated soils near the former smelters. The purpose of this study was to identify as many of the bacteria samples as possible. By utilizing the Biolog® Microbial Identification System, six of the twenty isolates were positively identified. The remaining isolates either were not included in the Biolog® database or represent

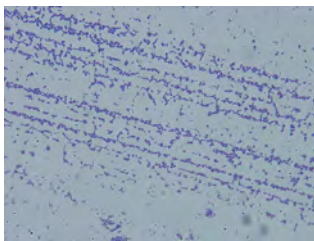
unidentified species or strains of soil bacteria. The identified bacteria included *Leifsonia aquatic*, *Rahnella aquatilis*, *Corynebacterium*, *Curtobacterium citreum*, and *Pseudomonas fluorescens biotype F*.

*Pseudomonas fluorescens biotype F* is a gram-negative, rod-shaped, catalase-positive, motile bacterial species. It is found in soil and survives best in a finer textured soil as compared to a coarser soil. *Rahnella aquatilis* (see image below) is also a gram-negative, rod shaped, nitrogen-fixing, motile bacterial species. It utilizes diverse carbon sources for its growth and can be found in both water and soil samples.



*Rahnella aquatilis*

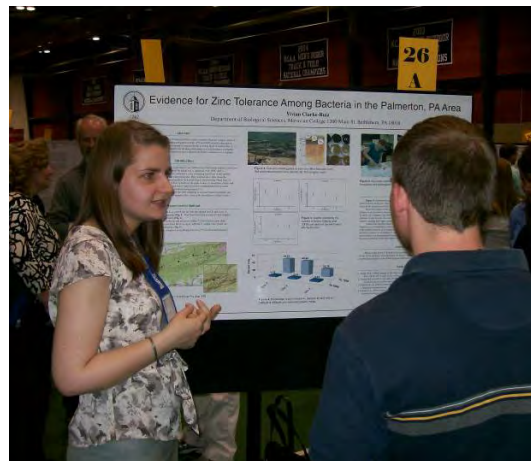
*Corynebacterium* is the genus within the broader “coryneform bacteria group” for which the most species have been described to date. *Curtobacterium citreum* (see image below) is a gram-positive, coryneform soil bacterial species.



*Curtobacterium citreum*

*Leifsonia aquatica* is a gram- positive, rod shaped, non-motile bacterial species found only in aerobic conditions. This species was first identified as *Corynebacterium aquaticum* by Leifson (1962), but the genus name was later changed to *Leifsonia*. He first extracted this species from water samples, but it can also be found in soil.

To better evaluate the microbial communities at the sample sites and hence obtain a better picture of community differences, the use of a community-level physiological profiling (CLPP) technique is recommended for future studies in place of, or in addition to, the MicroLog™ Microbial Identification System. The CLPP method allows for the examination of community metabolism over a week’s time, thus creating a profile of the entire bacterial community rather than just the identification of individual members that are randomly isolated from the soil.



Vivian Clarke-Ruiz presenting her research at Moravian College

## Arbuscular Mycorrhizal Fungi

Arbuscular Mycorrhizal Fungi (AMF) is a type of mycorrhizae that penetrates the cortical cells of the roots of vascular plants. It is an obligate symbiont that can help plants take up nutrients such as phosphorus and various soil micronutrients. They are of interest at the LGWR because they are frequently found in plants growing on mineral soils (the incidence of their colonization actually is lower in nutrient-rich soils) and they are commonly found in temperate grasslands. An absence of mycorrhizal fungi can also slow plant growth in early succession or on degraded landscapes. Furthermore, the use of AMF in ecological restoration projects has been shown to enable host plant establishment on degraded soil and to improve soil quality and health.<sup>1</sup> In studies in which soil was inoculated with AMF during reintroduction of vegetation, it was demonstrated that a significantly greater long-term improvement in soil quality parameters was attained resulting in increased plant growth and soil nitrogen content and higher soil organic matter content.

Brenda Casper's lab at the University of Pennsylvania is interested in investigating the diversity and function of arbuscular mycorrhizal fungi (AMF) across the metal contamination gradient on Blue

Mountain. AMF form mutually beneficial associations with plant roots; in exchange for carbon, they facilitate plant uptake of soil resources, especially phosphorus, which is not very mobile within the soil. However, because of fungi's carbon demand, AMF can also act as parasites under conditions of high soil nutrients. The relationship between AMF and plants in heavy metal contaminated soils is not clear. AMF might prove detrimental if they increase uptake of metals, but on the other hand, they might improve the host's overall wellbeing in a way that enables the plant to better cope with heavy metals.

One study done by Jennifer Doherty involved the examination of the composition of the AMF spore communities across the contamination gradient and the degree that roots of the common cool season grasses are colonized by these fungi. Morphological characteristics of AMF spores, which are produced underground, have been traditionally used to identify species. Abundant spores were found across the contamination gradient but much lower species diversity than is typical of non-polluted grasslands. The relative abundance of the AMF species differs between soils with high and low levels of metal contamination, suggesting that some species are better able to tolerate metals than others. For the cool season grasses *Deschampsia flexuosa* and *Danthonia spicata*, root colonization rates by putative root pathogens (4 %) was greater than colonization rates by AMF (2-3 %), which suggests these grasses are not highly AMF

---

<sup>1</sup> Jeffries, P., Gianinazzi, S., Perotto, S., Turnau, K., Barea, J. (2003). The Contribution of arbuscular mycorrhizal fungi in sustainable maintenance of plant health and soil fertility. *Biology and Fertility of Soils* 37: 1-16.

dependent. A greenhouse experiment with *Da. spicata* in the metal-contaminated soils did show that plant growth is slightly improved by the presence of AMF.

Sydney Glassman, a graduate student, focused on the individual species of AMF. She conducted greenhouse experiments to determine if some AMF species are more tolerant of high levels of metal contamination than others, whether some species are more helpful to their plant hosts, and whether ecotypic variation is evident in the fungi. That is, does the same AMF species taken from soils at the high and low ends of the contamination gradient show functional differences? AMF reproduce asexually, so ecotypic variation is not common, but the heavy metal contamination should prove a strong selective force that could generate such differences. Glassman also oversaw a high school student's project with the warm season grasses that were seeded on the mountain. From other research with *Andropogon gerardii*, *Sorghastrum nutans*, and *Schizachyrium scoparium*, it is known these species are highly dependent on AMF, and it is of interest to investigate the role of AMF in the successful establishment of these grasses on Blue Mountain. The plan is to determine the species of AMF associating with these plants in the contaminated soils and percentage of root colonized by AMF fungi and to compare the results with similar data from a serpentine grassland, where these grasses are naturally abundant. A presentation of this research entitled "***A context-dependent party for three: AMF,***

***non-mycorrhizal soil microbes, and plants in a pollution gradient***" was given at the August 2010 Ecological Society of America Annual Meeting in Pittsburgh, PA and a summary is included as Appendix E-5.

### **Other mycorrhizae studies**

Researchers from West Virginia University led by Drs. Jonathan Cummings and Dorothy Vesper are interested in a number of questions related to mycorrhizae, metal tolerance and stress responses in poplar trees, and poplar-rhizosphere responses to heavy metals. (The rhizosphere is a narrow region of soil that is directly influenced by root secretions and the associated soil microorganisms.) They have been studying zinc hyper-tolerance in eight hybrid species of popular genotypes and how native fungal species that form symbiotic relationships with poplar root systems can impact metal stress in these trees. They are interested in mycorrhizae from metal-contaminated sites and thus, they isolated soil samples from the LGWR. Their research involves a) analyzing the extractability of zinc and cadmium from the soils; b) how soil-metal interactions are impacted by the presence of mycorrhizae and c) examining a number of zinc-tolerance (biochemical) mechanisms in poplars. Such information could be useful in better understanding the heavy metal stress responses seen in early successional trees at the Refuge and in determining what measures might be important in re-establishing forests in some areas of the Palmerton Superfund Site.



## *Chapter 8*

# *Biota of the Lehigh Gap Wildlife Refuge – Plants*





# LGWR Biota – Plants

## Follow-up to the Plant Community Studies of the Ecological Assessment Part I

A main focus of Part I of the Ecological Assessment of the LGWR (finished in July 2007) was to inventory the plant species on the Refuge and identify and characterize the biotic or ecological communities. These communities are classified by the dominant plant species which, in turn, are highly influenced by the abiotic features such as bedrock, water supply, and exposure to sun. From the surveys done, 374 vascular plants were identified, of which 57% (214 species) are herbaceous perennials and 29% (110 species) are non-native. Sixteen species (4%) are rare or very rare. Based on the total number of plant species, one might conclude that there is great biodiversity on the Refuge; however, 73% of the species were rated as scarce. Only 12 species or 3% of the plants were considered abundant.

Since Part I of the LGWR Ecological Assessment was completed, four species of plants have been found that were not previously recorded. These include purple-leaved willow-herb (*Epilobium coloratum*), daisy fleabane (*Erigeron annuus*), sweetfern (*Comptonia peregrina*), and mountain mint (*Pycnanthemum tenuifolium*). Also, one species discovered during the previous study, bristly greenbrier (*Smilax hispida*) was noted in the text

on page 21, but was not included in the full listing of the vascular flora.<sup>1</sup> A number of native species have been introduced in the habitat gardens and in test plots in the grasslands (see below and Appendix F-1) since Part I of the assessment was completed.

Of the abundant species identified in the earlier assessment, some were early successional trees such as sweet birch (*Betula lenta*) and gray birch (*Betula populifolia*). Since then, the number of these birch saplings has increased dramatically in the grassland areas especially starting about one-third of the way up the mountain between the LNE and the Charcoal Trails. Many of these birch trees that are growing along either side of the LNE trail on the steep slopes of the ridge north of the Osprey House show signs of stress including leaf margin chlorosis, small leaf size and leaf curling, early leaf drop, and stunted growth.

---

<sup>1</sup> See Appendix A, Lehigh Gap Wildlife Refuge Ecological Assessment, 2007 available at <http://lgnc.org/wp/wp-content/uploads/2009/06/lgnc-ecological-assessment.pdf>.



**A young gray birch along the LNE Trail in July showing signs of stress**

Studies summarized in Appendix G and discussed in Chapter 9 determined that gray birch takes up zinc from the soil and accumulates it in leaf tissue to levels around 1000 ppm. This is consistent with the findings of BBL<sup>2</sup>; those studies showed that sweet birch also takes up metals from the soil. The leaf marginal chlorosis shown in the image below could likely be due to direct metal toxicity and/or damage caused by the formation of reactive oxygen species formed in the presence of the zinc and other heavy metals.<sup>3</sup>

<sup>2</sup> [Preliminary Human Health and Ecological Risk Evaluation and Data Summary Report – Warm Season Grass Remediation Area, 2004.](#) Prepared for Viacom International, Inc. by BBL (now Arcadis).

<sup>3</sup> A. Schützendübel and A. Polle, 2002. Plant Responses to Abiotic Stresses: Heavy Metal-Induced Oxidative Stress and Protection by Mycorrhization, *J. Expt. Bot.* 53: 1351-1365; 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.



**Leaf marginal chlorosis in Gray Birch from the LGWR**

The trees are also likely stressed from a lack of nutrients, especially nitrogen, due to the poor quality of the soil and from water deficits since there is little organic matter in the ground to retain water. The latter becomes a particular problem in mid-summer in Pennsylvania where short-term droughts are common.



**Evidence of stress in sweet birch leaves at the LGWR**

Two other trees that were described as abundant include sassafras (*Sassafras albidum*) and black gum or tupelo (*Nyssa sylvatica*). Stunted remnants of both of these trees were evident in what is now the grassland, even when the area was essentially denuded of most vegetation. Both

tree species are capable of vegetative (asexual) propagation; sassafras can readily form pure stands through suckering and black gum stumps sprout readily and larger stumps sprout and develop root suckers. Thus, it is believed that with the soil amendments added at the time of the grass seed planting, conditions improved enough so that the remaining stumps of these species were able to re-propagate more readily than trees that can only reproduce sexually. The high metal levels remaining in the ground are toxic to young seedlings and reproductive success was most likely hampered further by the acidic soil conditions, and the lack of cover exposing seeds to harsh winds, temperature extremes and strong sunlight.



**Photo of the grasslands in October 2008 showing sassafras and black gum trees**

Both types of birch have been shown to take up significant amounts of zinc. Sassafras trees, on the other hand, accumulate zinc at only about one-tenth of the levels of the birch (see Appendix G and BBL report<sup>4</sup>). The

---

<sup>4</sup> Preliminary Human Health and Ecological Risk Evaluation and Data Summary Report – Warm Season Grass Remediation Area, 2004.

reason for this is unknown, but it helps to explain why the sassafras trees do not show the same types of metal toxicity signs that the birch do. Metal uptake by black gum trees has not been tested at the LGWR site to date.

Another abundant species noted in Part I of the assessment is hay-scented fern (*Dennstaedtia punctilbula*). Large patches of this fern are typically indicative of over-browsing by white-tailed deer (*Odocoileus virginianus*). From the preliminary herbivory studies at the Refuge, the large number of tracks evident after a snowfall and the number of deer that have been photographed from the fall 2010 trail camera study (Chapter 3), there is clear evidence of a significant deer population on the site.

In Part I of the LGWR Ecological Assessment, it was noted that wild bleeding heart (*Dicentra eximia*) which is endangered in the state is surprisingly prevalent at the Refuge (and throughout the Palmerton area). In fact, it was noted that this may comprise the largest indigenous population of the species in Pennsylvania.<sup>5</sup> The population is still thriving at the LGWR along the mountain slopes, especially in ravines and erosion areas along the railroad rights-of-way (both the D&L and LNE Trails).

---

Prepared for Viacom International, Inc. by BBL (now Arcadis).

<sup>5</sup> See page 8 of the LGWR Ecological Assessment – Part I, 2007.



*Dicentra eximia*

Also noted in Part I of the assessment, the Lehigh Gap area is the sole known location in Pennsylvania for Pitcher's stitchwort or glade sandwort (*Minuartia patula*; syn. *Arenaria*). This plant is known to be in a group of metal "hyper-accumulators". From studies described in Appendix G, sandwort samples taken from along the LNE trail within the Refuge had levels of more than 3000 ppm zinc in the vegetative tissue which is three times higher than has been observed in birch leaves. Earlier studies by Marilyn Jordan at Rutgers found specimens with levels of zinc as high as 15,000 ppm<sup>6</sup>.

It has likely thrived on the contaminated slopes, in part, because of its ability to tolerate high levels of metals. For decades, it had little competition, and in observations since 2005, we have seen no evidence of insect herbivory on this plant.



*Minuartia patula*



**Sandwort in bloom in the LGWR grassland.** Light patches seen on the ground along the slopes in the image below are sandwort plants in bloom in early June. The Bobolink Trail runs along the diagonal boulder line on the left side of the photo and the D&L Trail can be seen along the bottom of the photo.

In 2008 and 2009, Sarabeth Brockley and Diane Husic from Moravian College began documenting the location through GPS coordinates and size of sandwort populations at the Refuge and in the Palmerton region.

---

<sup>6</sup> Jordan, M.J. 1975. Effects of zinc smelter emissions and fire on a chestnut-oak woodland. *Ecology* 56: 78-91.





Some of the major patches of sandwort that were sampled for the 2008 metal uptake studies are shown in the map below. Large patches of sandwort have not been observed above approximately 800 feet on the ridge.



**Map of sandwort populations studied**

The photo below shows this area of the grassland with the sandwort in bloom (the light patches in the middle of the slope). Above the sandwort, the tree line can be seen; sandwort has not found above this point on the slope.



Interestingly, as one heads west along the LNE trail past the original West Plant smelter site (upwind from the direction the pollution traveled) both the number of sandwort plants and the size of the patches of growth diminish. The ravine (Smilax Hollow) in this region has much greater plant diversity and a significant patch of Canada wild-rye (*Elymus canadensis*) which may be out-competing the sandwort. Presumably, the soil metal levels are lower in this region as well.



**Smilax Hollow**

Likewise, while sandwort grows extensively along the lower slopes of



the Kittatinny Ridge and Stoney Ridge (the next ridge north of the Kittatinny Ridge) in the areas close to the two smelter sites, by the time you reach the Carbon County Fairground area along Little Gap Road (3.2 miles from the east plant), sandwort plants are no longer found. This may be due to changing habitat as you approach the wetlands surrounding the Aquashicola Creek in the Little Gap area just to the west of Blue Mountain Ski Area. But the metal contamination is likely much less significant this far downwind from the eastern-most smelter that was in Palmerton. The hypothesis is that as metals become less bio-available and other plants in the restoration area become more abundant, *Minuartia* will eventually be out-competed. Thus, this plant may serve as a bio-indicator of recovery in the contaminated areas.



**Sandwort in bloom.** Light colored areas are the sandwort flowers; photo taken at the base of the Kittatinny Ridge downwind from the East Plant smelter.

### **Invasive Plant Species**

A list of the non-native and invasive species (approximately 20) were provided in Part I of the LGWR Ecological Assessment and management of invasive plants was

one of the key stewardship issues discussed in the recommendations section of that report.

In 2008 East Penn Township significantly cleared the brush along the D&L Trail to widen the space for future improvements to the trail. In doing so, they removed a significant amount of shrubs, much of which was invasive, especially some of the large Butterfly-bush (*Buddleja davidii*) plants. Without management, these plants will all grow back. *Buddleja* continues to be a problem on the Refuge propagating freely along the rail beds and in the grassland. Thousands of plants have been pulled by volunteers, but if any root remained in the ground, bushier shrubs came back immediately. The LGNC now routinely employs trained interns to eradicate this plant in sensitive areas using backpack sprayers and the herbicide Crossbow which contains 2,4-D and Triclopyr. This kills broad leaved plants but not grasses.



*Buddleja davidii*

Over the past few years, there have been a number of disturbances due to road work and construction. These sites are prime areas for invasion by garlic mustard (*Alliaria petiolata*). Diligent monitoring and control (hand-pulling) will be needed. Significant spreading of other invasive species has not been noticed. A significant amount of the *Phragmites australis* was removed during pond restoration work (Fall 2010) and in work to establish a new boat launch on the Lehigh River to the immediate south of the Refuge (to the east of the entrance road). This may help to slow the spread of this reed.

One exceptionally aggressive invasive species is oriental bittersweet (*Celastrus orbiculatus*) which grows along the D&L Trail. It is not known if this plant has taken advantage of the brush clearing that was done or if weather conditions have been ideal for its growth.

### Status of the grasslands

Visitors to the Refuge—including hikers and botanical experts—routinely comment about the progress of the restoration. The grasses have filled in large areas along the slopes of the mountain; although bare rock areas still remain. Arcadis staff, along with students from various schools and local colleges and universities, continues to monitor percent vegetative cover and succession studies are being conducted (see Chapter 9).



In early September 2009, Roger Latham hiked through the grasslands to survey the progress and was struck the extent of grass cover along the mid- and upper slopes that were seeded by aerial application. He and others have noted that the Canada wild-rye (*Elymus canadensis*) is of particularly high density at mid-slope. At that time, he suggested that this might be due, in part, to the unusual cooler weather during the summer of 2009. However, this grass continued to thrive in the summer of 2010 which was much warmer. The high density of this cool season (C3) species may have set back the establishment success of the warm-season grasses in that part of the slope. Time will tell whether the wild-rye growth will scale back and the warm-season grasses will begin to burgeon at the higher elevations. Regardless, the establishment of any grass on the steeper slopes provides excellent erosion-control cover and wildlife habitat.



Latham also commented about the eastern part of the ridgetop. He had previously seen low numbers of rough bentgrass (*Agrostis scabra*) over the ridgetop, but not in such large patches. It is interspersed with common hairgrass (*Deschampsia flexuosa*) and one of the minority cool-season grasses that flower and fruit through late summer and fall (like Canada wild-rye).



Latham commented on how interesting it is to observe the changes that plant communities go through during unusual weather conditions and during this restoration process. Because of the experimental nature of this entire project, it is precisely these changes and species interactions that will be important to monitor for years to come.



In the grassland, especially in areas that still have low percentages of vegetative cover, lichens been observed amongst the rocks and remnants of tree logs and in areas of crusty black dirt. These tend to be some of the most highly contaminated areas. Howe and Lendemer describe their May-June 2006 survey of lichen communities at the Lehigh Gap and note the substantial recovery that had occurred since the 1972 Nash study.<sup>7</sup> On September 30, 2010, while doing a walk through of the area between the LNE and D&L Trails just east of the Bobolink Trail, fruiting bodies of lichen were documented for the first time (see photo below).



<sup>7</sup> Appendix E, LGWR Ecological Assessment Part I, 2007.



At the bottom of the photo on the previous page, the green rosettes of sandwort (*Minuartia patula*) that appear in fall are obvious. What was unusual was that some of the sandwort plants were blooming – something that had not been seen previously at this time of year (see photo below).



Another surprise that day was evidence of the old tree logs rotting – an indication that some decomposers have returned to the site.



The photo below was taken in summer 2007 when bare patches along the LNE trail edge were still obvious and places where erosion, especially along the trail edge, was possible.

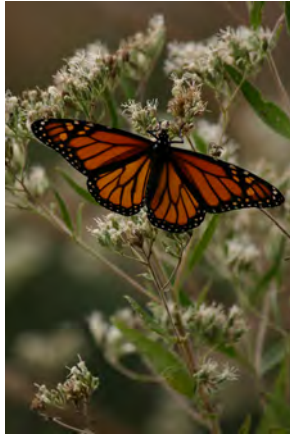


The original grass seed mixture used on these steep slopes included several cool season fescues, which sprouted quickly and shaded out the slower germinating warm-season sprouts, eliminating the warm-season species in this area. The fescues died in ensuing years, leaving behind these barren areas. In retrospect, it was not a good idea to include the fescues in this mix, as places where the fescues were not added are today fully stocked with grasses. These areas have since been reseeded to increase the vegetative cover and minimize the erosion potential, but bare patches still remain. The trees visible in the photo to the right have grown significantly helping to stabilize the steep slope.

### **Habitat Enhancement**

The goals of the EPA's Record of Decision for the Palmerton Superfund Site at the LGWR site are being met: there is revegetation with native species, the erosion has generally been halted, and metals are, for the most part, are only accumulated in the vegetation at low levels deemed safe for wildlife and human receptors. However, warm season grasses alone do not create a healthy biotic community which includes a suite of decomposers, mycorrhizal fungi, and a host of

consumers from insects and small mammals to songbirds and predators. The plant community within the grasslands is diversifying with forbs such as goldenrods (*Solidago* spp.), blue vervain (*Verbena hastata*), and late eupatorium (*Eupatorium serotinum*) becoming notable. Invasive species such as butterfly bush (*Buddleja davidii*) and tree-of-heaven (*Ailanthus altissima*) are invading the site but are being removed as they are found. But, in general, the diversity of the plant community is still low.



LGNC is working to increase the diversity of the restoration area with the introduction of a variety of native forbs that provide pollen, nectar, seeds, and forage for a wider variety of consumers. This increase in plant diversity should not only increase the diversity of other species, but also provide more long-term stability to the ecosystem. (Appendix F-1 is a database of all the plants that have been introduced in various studies at the Refuge.) Invasive species removal will continue as well as we attempt to manage the trajectory of succession with the goal of a diverse prairie ecosystem. As we increase the diversity, we will also need to evaluate uptake of metals by these introduced species to ensure we are

not mobilizing the metals to an extent that poses a risk to consumers.

### ***Grassland Perennials:***

In 2006, seed from eleven species of plants were spread in the grassland:

- Partridge Pea  
(*Chamaecrista fasciculata*)
- Wild Senna  
(*Senna hebecarpa*)
- Wild Lupine  
(*Lupinus perennis*)
- Round-head Lespedeza  
(*Lespedeza capitata*)
- Butterfly Milkweed  
(*Asclepias tuberosa*)
- Common Milkweed  
(*Asclepias syriaca*)
- Ox eye Sunflower  
(*Heliopsis helianthoides*)
- Black-eyed Susan  
(*Rudbeckia hirta*)
- Brown-eyed Susan  
(*Rudbeckia triloba*)
- Smooth Blue Aster  
(*Aster laevis* = *Symphotrichum laevis*)
- Dense Blazing Star  
(*Liatris spicata*)

It was feared that none had germinated until 2009 when seven of the eleven species were found blooming. The summer milkweed species were first to bloom. The following images were taken in August 2009.





**Ox eye Sunflower**



**Brown eyed Susan**



**Partridge Pea**



**Black eyed Susan**



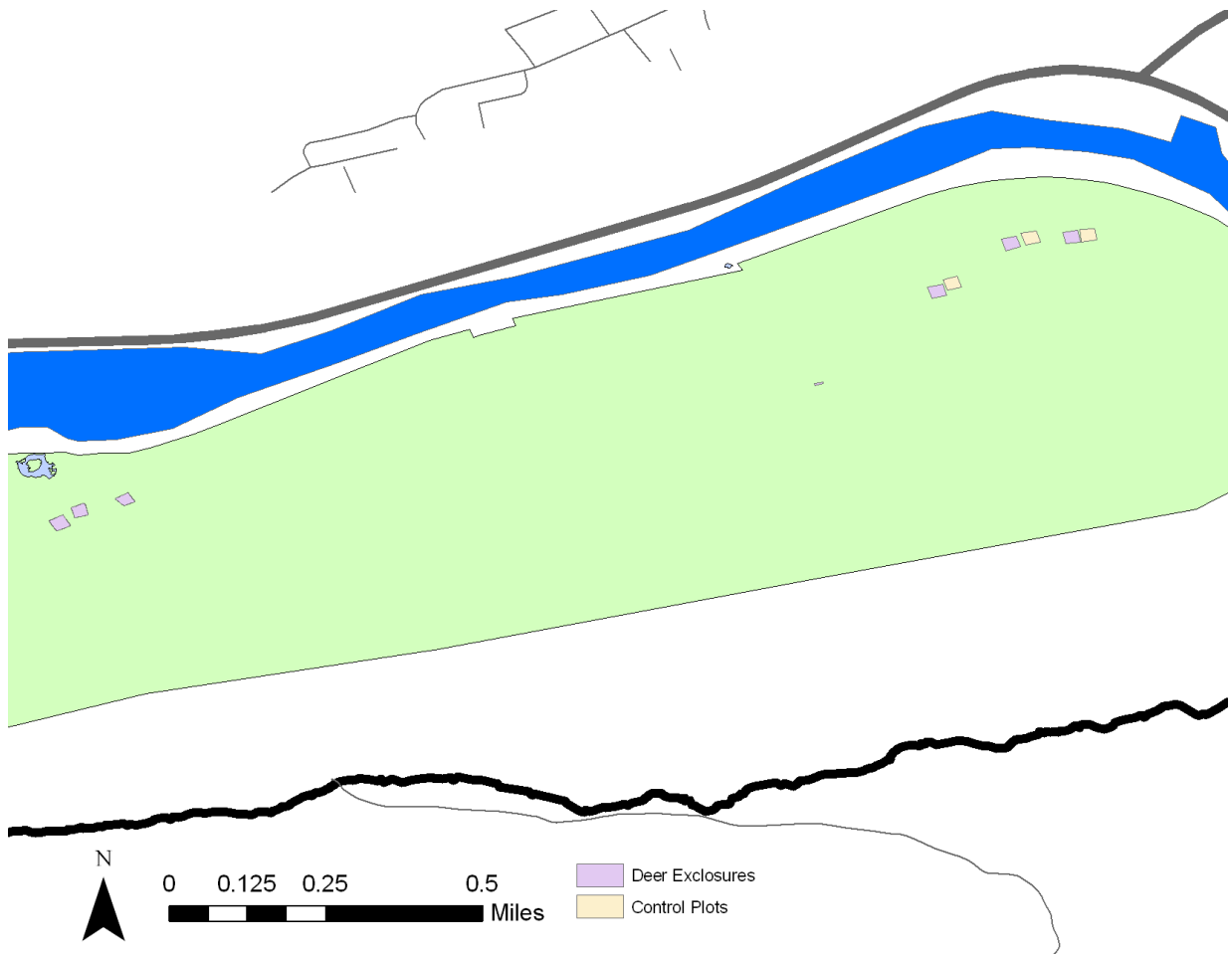
**Wild Senna**

There are two major factors that may limit the type of forbs that can be established and sustained: 1) physical conditions of the site (low nutrient levels, lack of organic soil, and high metal concentrations), and 2) browsing by herbivores, primarily insects, small mammals, and deer. Since it is not known which species will be affected by these factors, and since it is costly to introduce these plants, a controlled experimental planting of a variety of forbs to monitor their success has been designed and implemented.



The details of the ***Habitat Enhancement and Deer Exclosure Studies*** are described in a report included as Appendix F-2. This project, funded by an Audubon

*TogetherGreen* Innovation grant, involved the systematic planting of 150 plugs each of nine native species (six in spring and three in fall; see table below on page 8-14 for species used). A number of individuals provided expert advice on the selection of species and design of the experimental plots including Roger Latham, Sue Tantsits, Louise Schaeffer, and Everett Warren. Deer exclosures were installed by Everett Warren and staff from Green Man Enviroscaping (see locations in map on the following page).



**Location of the Deer Exlosures and Control Plots at the LGWR**

Planting was accomplished with a large corp of LGNC volunteers and students from Moravian College.



The locations of each plant were marked with flags and GPS coordinates. One half of these were planted inside of deer exclosures; the other half in control plots outside of the exclosures. Monitoring commenced in June 2009 for the spring planted species to determine the effects of the physical conditions on the establishment and growth of the forb species, as well as the effects of herbivory. Because each exclosure (fenced) plot is paired with an unfenced control plot, monitoring should be able to separate the effects of herbivory by insects and small mammals from that of deer browsing. Small mammals such as voles may also be significant browsers on herbaceous vegetation both inside and outside of the exclosures. The plan is to also use inked tiles to monitor small mammal presence in the test plot areas in the future.

**Forb species planted in test plots\***

| <b>Common Name</b>        | <b>Scientific Name</b>     | <b>*Spring/Autumn Planting</b> |
|---------------------------|----------------------------|--------------------------------|
| Butterfly Milkweed        | <i>Asclepias tuberosa</i>  | Spring                         |
| Wild Bergamot             | <i>Monarda fistulosa</i>   | Spring                         |
| Coreopsis                 | <i>Coreopsis tripteris</i> | Spring                         |
| Sundrops                  | <i>Oenothera fruticosa</i> | Spring                         |
| Brown-eyed Susan          | <i>Rudbeckia trilobum</i>  | Spring                         |
| Three-nerved Joe Pye weed | <i>Eupatorium dubium</i>   | Spring                         |
| False Indigo              | <i>Baptisia australis</i>  | Autumn                         |
| Stiff Goldenrod           | <i>Solidago rigida</i>     | Autumn                         |
| Smooth Aster              | <i>Aster laevis</i>        | Autumn                         |

\* Some violets that may be important for the Regal Fritillary butterfly have also been planted inside the exclosures to determine their viability at the site (See Chapter 6).



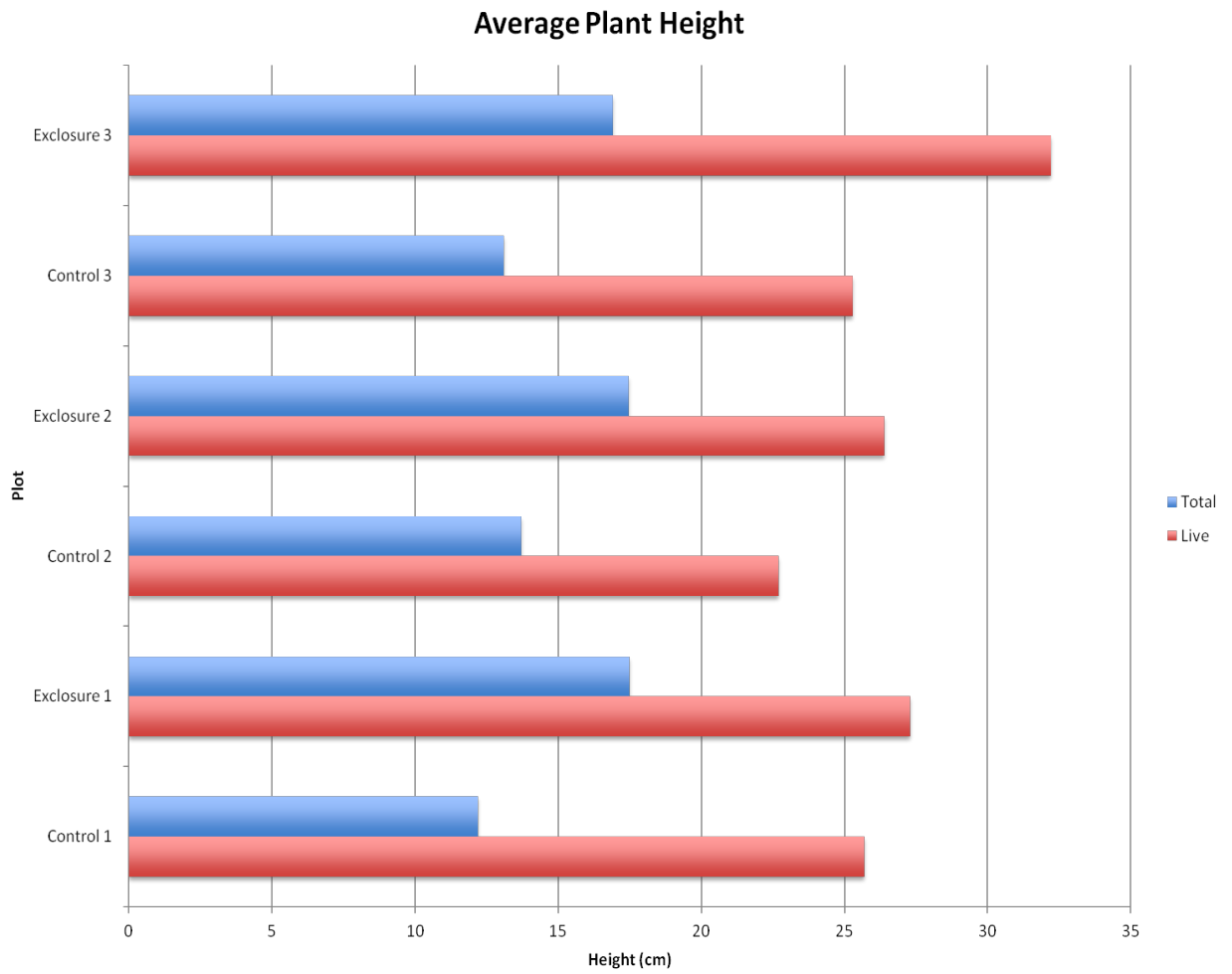
As of August 2009, 66% survival of the plants was recorded with no significant difference between the areas within or outside of exclosures. Survival rates of four species were above 70% (*Oenothera*, *Coreopsis*, *Monarda*, and *Rudbeckia*), while two were under 50% (*Eupatorium* and *Asclepias*). Unfortunately, after the spring planting, the spring weather was unusually hot and dry and many young plants died. Browsing pressure varied among species with the number of plants showing browsing ranging from 4 to 55% for the six species.

Three species (*Baptisia australis*, *Solidago rigida*, and *Aster laevis*) were planted in late August 2009, completing the planting in the experimental plots. Monitoring continued in 2010 and will be ongoing. In July of 2010, heights of surviving plants were measured. Average plant height divided by the total number of specimens planted was plotted (blue bars) as was average plant height divided by the number of surviving (live) plants (red bars). The first plot represents all species combined and the second represents results by individual species. The comparison between the red and blue bars gives a sense of survival rate of the plants.

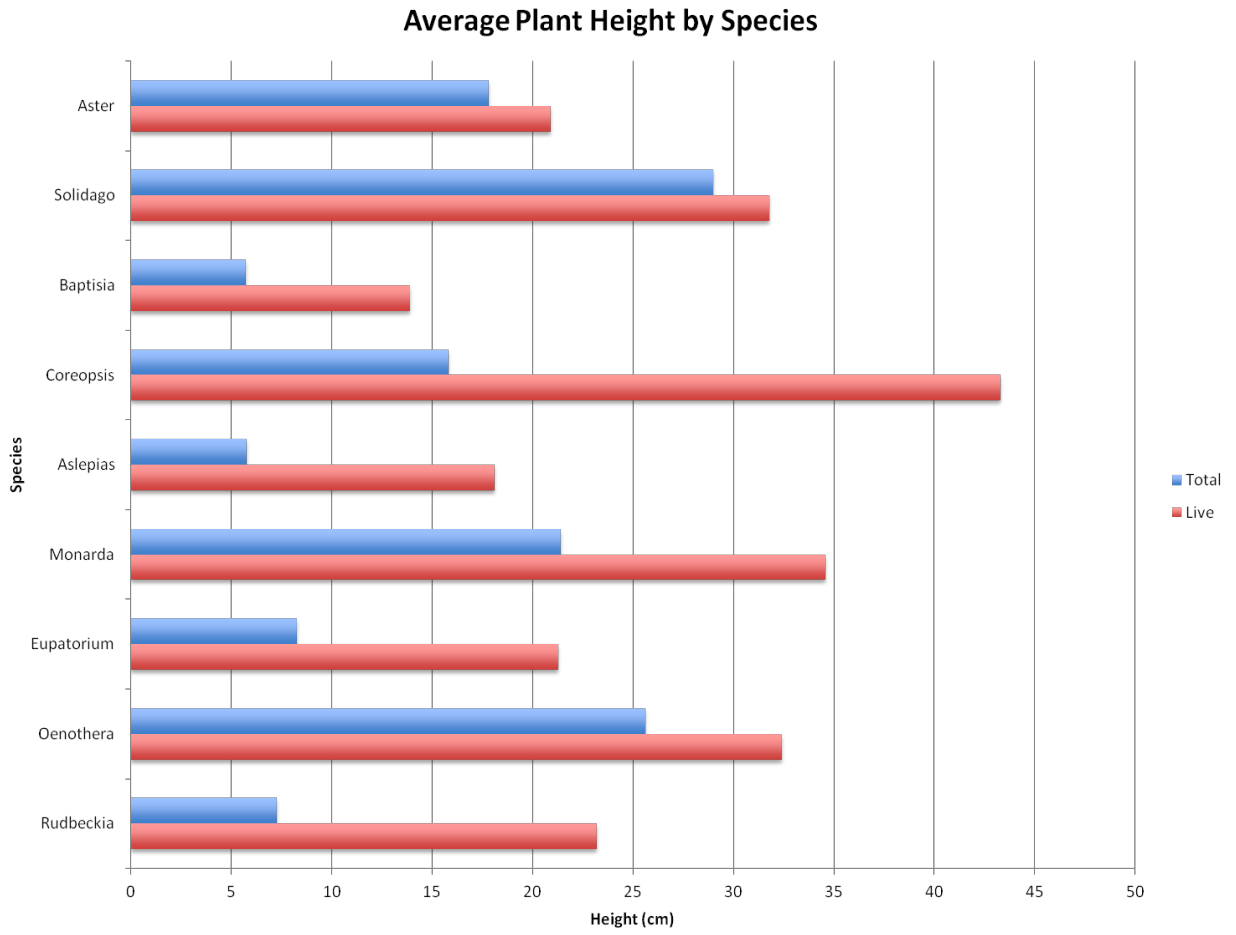


It is anticipated that the results of this study will allow the LGNC to implement full-scale enhancement of the grassland in a cost-effective way with those species that are best able to survive here. This will also provide easily located plants for metal uptake studies in the future since it is important to know whether introduced plants take up the heavy metals from the soil.





**July 2010 Total Plant Growth and Survival Assessment  
LGWR Habitat Enhancement Study**



### July 2010 Growth and Survival Assessment by Species Type LGWR Habitat Enhancement Study

Three experimental 30 meter square exclosures were also installed on the forested part of the Refuge. Two of these plots were heavily covered with Hay-scented Fern. Herbicide was used to kill the ferns inside half the exclosure and in a similar-sized area outside the exclosure in the adjoining control plots. Monitoring of these plots will help determine what is inhibiting herbaceous, shrub, and understory vegetation and tree regeneration in these areas of the Refuge. Hypotheses include metal contamination, deer browsing pressure, and the abundance of ferns preventing normal habitat development in these forests.

### ***Tree Planting Field Trials***

In 2007, Abel Boyer, a resident of the region wanted to conduct a Boy Scout project at the LGWR. His father provided fourth-generation backcross Chestnut Tree hybrids from the American Chestnut Foundation which Abel planted in an area between the D&L and LNE Trails just to the east of the Bobolink Trail. The trees are protected by tree tubes to minimize deer browsing and provide shading from sun. Abel frequently watered these during the first year. As of fall 2010, most are doing quite well and most have now grown taller than the tree tubes.



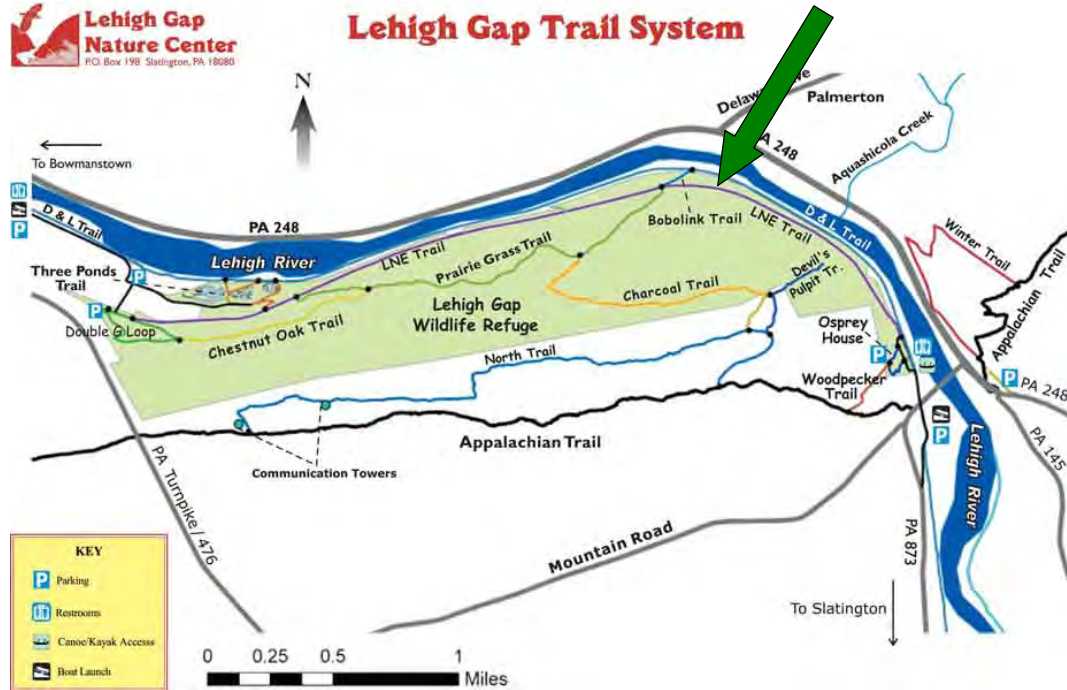
**Chestnut sapling**

In order to test the viability of the Superfund Site for supporting growth of trees, a trial planting of 126 acorns or seedlings was initiated in 2007 with advice from Dave Henry, the forester for the PA Game Commission, Ken Beard of the PA Department of Environmental Protection, and Jim Frank, the environmental engineer from Frank and West, Inc. The planting was done by a large number of LGNC volunteers in the test area between the D&L and LNE Trails just to the east of the Bobolink Trail (see green arrow on the map on the following page). About ten each of the following acorns and about seven seedlings were planted:

- White Oak (*Quercus alba*)
- Chestnut Oak (*Quercus prinus*;  
syn. *Q. montana*)
- Black Oak (*Quercus velutina*)
- Red Oak (*Quercus rubra*)
- Bur Oak (*Quercus macrocarpa*)
- Scrub Oak (*Quercus ilicifolia*)

In addition, some Post (*Quercus stellata*) and Blackjack Oak (*Quercus marilandica*) acorns and seedlings, provided by Ken Beard, were planted in lesser numbers. A map of the

specific planting locations and a spreadsheet of observations (survival and growth) from May 15, 2008 are included in Appendix F-3.



Location of Tree Planting Field Trials (in area of green arrow)

On October 9, 2008, Maria Tranguch surveyed the field trial area and found 30 living oaks: 25 that had been planted as seedlings and five as acorns. Some of the surviving looked healthy; others looked stressed. Survival by species was as follows:

|                         |   |
|-------------------------|---|
| Red Oak acorns          | 4 |
| Chestnut Oak acorns     | 1 |
| Black Oak seedlings     | 2 |
| Red Oak seedlings       | 2 |
| White Oak seedlings     | 2 |
| Bur Oak seedlings       | 5 |
| Chestnut Oak seedlings  | 8 |
| Blackjack Oak seedlings | 5 |
| Post Oak seedlings      | 1 |

Conclusions from this field test include:

1. Planted acorns did not do well. Red oak acorns seem to have done the best, but this is a small sample size.
2. Chestnut and Blackjack Oak seedlings did well.
3. Just over half the seedlings have survived one year; only about 7% of acorns germinated and survived.

Blackjack Oak (*Quercus marilandica*), a small oak of the red oak group is not native to the region, but is found in the southern and central United States, in parts of the coastal plain of New Jersey, and in the State Line Serpentine Barrens that straddle the Pennsylvania-Maryland border. This tree grows in poor, thin, dry, rocky or sandy soils where few other woody plants can thrive, usually on low ground, from sea level up to 900 m altitude. It often occurs near Scarlet (*Quercus coccinea*) and Post Oaks (*Quercus stellata*) as well as Pitch Pine

(*Pinus rigida*); understory companions include winged sumac (*Rhus copallinum*), bracken fern (*Pteridium aquilinum*), and sweetfern (*Comptonia peregrina*).



Blackjack Oak Seedling

### ***Prairie Warbler Trail Shrub Habitat Enhancement***

Adjacent to the Osprey House Visitor and Education Center at Lehigh Gap is a 100' power line right-of-way (ROW) that must be kept clear of tree species that would grow up and potential damage the 512KV power lines. The result of utility management on the metal contaminated hillside under the power line is a scrub habitat dominated by meadowsweet (*Spiraea latifolia*), several sumacs (*Rhus typhina* and *Rhus copalina*), and pioneering gray birch (*Betula populifolia*) and sassafras (*Sassafras alba*) trees. Every few years, the utility company (PPL Corporation) would cut the sassafras and any other tree species that could reach the lines overhead.

The very first spring at the site in 2003, it was immediately noticed that the scrub area was home to nesting Prairie Warblers and Indigo Buntings. The LGNC quickly became interested



in managing this unique early successional (scrub) habitat. Such habitat in Pennsylvania is by nature temporary, since it will continue through succession to become a forest if left alone. In pre-colonial times, disturbances such as beaver activity and fire (both natural and intentionally set by Indians) ensured that there was always an ample supply of scrub habitat. Few beavers and the suppression of fire for more than a century have resulted in a dearth of early successional habitat in the East. Power line rights-of-way present an opportunity for management of early successional habitats.



***Spiraea latifolia***

A suite of plants, invertebrates and vertebrates depend on scrub habitat for survival. This habitat is critical breeding habitat for Prairie Warblers, but is also favored by a host of other bird species such as Field Sparrows and Indigo Buntings. The addition of

nest boxes quickly resulted in breeding Tree Swallows, Eastern Bluebirds, and House Wrens. The first Blue Grosbeak reportedly seen at Lehigh Gap Wildlife Refuge was in this area (2005) and more recently, the first reported breeding Blue Grosbeaks in Carbon County have been observed in scrub habitat in a ravine (Grosbeak Gulch) within the grasslands (Chapter 5). Butterflies and native bees also benefit from early successional habitat. Both rely on nectar sources, such as the *Spiraea* blossoms, and the bees find nesting habitat in the soil among the shrubs. The LGNC Naturalist Club bee trapping project found numerous species of native bees in the transects through this habitat.

In 2006, the LGNC began the first habitat gardens project on the south side of the original Osprey House building. The plan included the power line ROW, which was to be enhanced with a variety of native wildflowers and shrubs. Girl Scout Marci Barr approached the LGNC at that time about a Gold Award project (equivalent to the Boy Scout's Eagle Scout award). Together with LGNC staff, Barr chose ecological enhancement of the power line area as part of her project. The other part was to create an interpretive brochure and self-guided nature trail (the Prairie Warbler Trail) through this habitat. The trail itself was built by Doug Beam as part of his Eagle Scout project.

Barr researched the native plants of the area that would be appropriate in the climate and soil conditions of the Prairie Warbler Trail area and consulted with Linda Frederick

(originator of the habitat gardens plan) and Sue Tantsits and Louise Schaeffer at Edge of the Woods Native Plant Nursery. Barr selected a variety of plants and introduced them to areas along the trail. These species included:

- Wild Lupine  
(*Lupinus perennis*)
- Summersweet  
(*Clethra alnifolia*)
- Silky Dogwood  
(*Cornus amomum*)
- Elderberry  
(*Sambucus canadensis*)
- American Hazelnut  
(*Corylus Americana*)
- Low bush blueberry  
(*Vaccinium angustifolium*)
- Pasture Rose  
(*Rosa Carolina*)
- American Cranberry Viburnum  
(*Viburnum trilobum*)

Barr also spread seeds of the following species:

- Ox-eye (False) sunflower  
(*Heliopsis helianthoides*)
- Blazing star  
(*Liatris spicata*)
- Partridge Pea  
(*Chamaecrista fasciculata*)
- Wild Senna  
(*Cassia hebecarpa*)



A very intense short-term drought occurred before the plants were well established and many of them died. Deer browsing also eliminated some of these plants and few survived.



In 2009, Naturalist Club member, Brandon Everett, received a Naturalist Fellowship for his project to continue the enhancement of the power line ROW and to manage the habitat as a high quality scrub habitat. He and

LGNC Director Dan Kunkle met with representatives of PPL at the site and Everett gained permission to manage the area, with the provision that if he failed to keep trees from growing into the lines, PPL would resume management. That summer, Everett and LGNC volunteers cut all the tree species that had grown up since PPL's most recent maintenance, and began planting appropriate native species on the site. They also removed all invasive species from the area.

Everett's project was funded with money from Kunkle's *TogetherGreen* Fellowship grant. As did Marci Barr, Everett researched the native plants of the area and consulted with the Edge of the Woods staff. He used his Naturalist Fellowship funds to purchase plants at Edge of the Woods, and installed them along the Prairie Warbler Trail. This project is ongoing. Species introduced to the area to date by Everett include a single specimen each of the following, planted in late August, 2009:

- Ox-eye (False) Sunflower  
(*Heliopsis helianthoides*)
- Tall Tickseed  
(*Coreopsis tripteris*)
- Virginia Rose  
(*Rosa virginiana*)
- Woodland Sunflower  
(*Helianthus divaricatus*)
- Tennessee Coneflower  
(*Echinacea tennesseensis*)
- Prickly Pear Cactus  
(*Opuntia cactaceae*)
- Giant Coneflower  
(*Rudbeckia maxima*)
- Butterfly Weed  
(*Asclepias tuberosa*)

- New York Aster  
(*Aster novi-belgii*)
- Strawberry Bush  
(*Euonymus americana*)
- Pinxter Azalea  
(*Rhododendron periclymenoides*)
- Summersweet  
(*Clethra alnifolia*)
- False Indigo  
(*Baptisia australis*)
- Highbush Blueberry  
(*Vaccinium corymbosum*)
- Gooseberry  
(*Ribes rotundifolium*)



***Heliopsis* sp.**

Everett also planted ten smooth asters (*Aster laevis*) and ten stiff goldenrods (*Solidago rigida*) that were donated by Edge of the Woods. One month later, Everett planted the following species that were donated by Barbara Malt from her gardens:

- Blue Mistflower  
(*Eupatorium coelestinum*)
- Trumpet Honeysuckle  
(*Lonicera sempervirens*)
- Eastern Columbine  
(*Aquilegia canadensis*)



While Everett’s plantings also suffered from short-term drought and deer browsing, his plantings have met with some success and the habitat diversity has increased. Continued maintenance (tree removal) is necessary and additional plantings could continue to increase the value of this habitat to wildlife.

Management of land in gas line easements and under power lines is important given that the disturbance

can readily lead to erosion and invasion by non-natives. The trials in the Refuge shrub habitat could provide information for alternative management practices throughout the region. Since the Prairie Warbler Trail goes around and through this habitat, signage and a detailed trail map can help educate the public about valuable habitats and redefine what constitutes a garden.



**An Aerial View of the LGWR Shrub Habitat in the area of the PPL Power Line Right-of-Way**

### *Habitat Gardens*

In 2006, with an initial donation from Linda Frederick and Michal Kubik, the LGNC began a Habitat Gardens Project at the Osprey House area of the Refuge. Frederick and Diane Husic have been the directors of

this project with Bill Mineo, Sue Tantsits, and Louise Schaeffer serving as consulting advisors. The source of the plant materials for the gardens is Edge of the Woods Native Plant Nursery in Orefield, PA. The primary purposes of the garden are: 1) create habitat for native bees, birds, butterflies, and other species; 2) demonstrate to the public the use of native plants and the concept of creating habitat gardens; and 3) create educational teaching areas for classes visiting the Refuge.

In these gardens, native is defined as plants native to the mid-Atlantic region, along with commercially available cultivars of natives. The gardens are also experimental plots allowing the LGNC to determine which plants will survive at this site given the soil, weather, and contamination conditions and the herbivory pressure.



**Native Bog Garden at LGWR**

Suburban sprawl in southeastern Pennsylvania has led to thousands of housing developments with large homes and yards of mowed lawns (monocultures). Care of these lawns, planted with non-native cool-season grasses, is often accompanied with the use of chemical fertilizers and pesticides, often far in excess of per/acre usage in agricultural settings. These large expanses of mowed grass provide little habitat for wildlife of any kind. In addition, most of the gardens associated with these homes are filled with exotic plants (often invasive species) and mulched with chipped hardwoods. These gardens also provide little in the way of habitat for wildlife and often utilize invasive species that can colonize and degrade nearby natural landscapes.



As so eloquently described in Doug Tallamy's book, Bringing Nature Home<sup>8</sup>, minimizing areas of mowed grass and using native plants in gardens would allow suburban areas to provide habitat for a wide variety of wildlife, especially for birds, butterflies, and native pollinators. Native insects need native plants to feed upon, and 96% of our bird species eat insects at least during the nestling period.



Native butterflies also need native plants. While nectar from exotic plants is similar if not identical to nectar in natives, butterflies need larval food plants as well as nectar. Without the proper native plants on which to lay its eggs, you will not support the full life cycle of any butterflies. Native bees also need native plant pollen to provision their young. These invertebrate species can be benefited even by small gardens with native plants.

In addition to the benefits to wildlife of native plant, there are other benefits as well. Once established, native plants need little care, need no fertilizer or pesticides, and require

little if any watering. In the long term, this saves money and time for the homeowner.



**The First Habitat Garden at LGWR**

The LGNC hopes to convince many area suburban residents to add native plants to their landscaping. A big barrier to succeeding with this educational process is tradition. Most gardeners prefer exotic plants with large, showy flowers, and perfect foliage that is not eaten by insects. Native plants are the base of the food chain and get eaten by a variety of insects. However, this herbivory rarely gets out of hand to destroy entire leaves or plants because predatory insects and birds control the populations of the herbivorous insects. Native plant gardeners must understand that imperfect leaves on their plants means the plants are forming the basis of a healthy food web. For a healthier environment, the public needs to be re-educated about gardens (and the ecological role that they can play) and re-define beauty as nature in balance and working properly, rather than showy, perfect plants.

The habitat gardens at the Osprey House now include nearly an acre of planted and mulched beds, rock

<sup>8</sup> Tallamy, Douglas W. 2007. Bringing Nature Home: How Native Plants Sustain Wildlife in Our Gardens. Timber Press, Portland, OR.

gardens, a bog garden, and habitat plantings along our driveway and in the Prairie Warbler Trail area. They range from highly tended gardens that would be acceptable to many suburban gardeners, to relatively unmanaged areas into which we have introduced native plants and removed invasive species.



**Part of the New Habitat Garden  
Established in Summer 2010**

These habitat garden plantings have been undertaken in an experimental fashion. Native plants that seem appropriate for the soil and climate conditions that exist at the Refuge were selected. There are elevated levels of metals in the soil from the zinc smelters with which the plants must contend. As noted above, these gardens are also field trials of what plants will survive and thrive in the conditions present. A database of all species planted in the gardens has been compiled (See Appendix F-1), and the gardens are being monitored to determine which species do well here over the long term.

# *Section III*

## *Ecological Studies, Abiotic Parameters, and Risk Assessment*

As noted in the Introduction and Chapter 8, the aims of LGNC for the restoration project go well beyond meeting the goals of the EPA's Record of Decision for the Palmerton Superfund Site. Besides revegetating the mountainside with warm season grasses, the LGNC hoped to create a thriving habitat to support wildlife and serve as a model of not only restoration, but conservation for the Kittatinny Ridge. The Lehigh Gap Wildlife Refuge was to be open to the public as a safe and interesting place for passive recreation. A goal was also to have a site for educational opportunities for the public and it has turned out that it serves this role not only through programming for the general public, K-12 classes, college and university students, and teachers,

but also for conservation professionals and scientists.

Ongoing research is providing information, not only about the biodiversity at the Refuge as described in previous chapters, but also about how the site is functioning ecologically (succession, food webs, metal uptake by vegetation), microclimates at the Refuge, the fluxes and transport mechanisms of groundwater and surface water contaminants, distribution and persistence of smelter-derived metals, and the impact of efforts to mitigate potential hazards at the site, and other forms of environmental risk assessment. A description of some of this work is included in Chapters 9 and 10.

## *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 revegetation 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.<sup>1</sup> 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.

---

<sup>1</sup> 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.<sup>2</sup> 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

---

<sup>2</sup> Lansing, Jennifer and Kathy Romaine. 2007. Draft Invasive Plant Management Plan, Operable Unit 1, Geographic Area 2. Arcadis BBL, Albany, NY.

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.



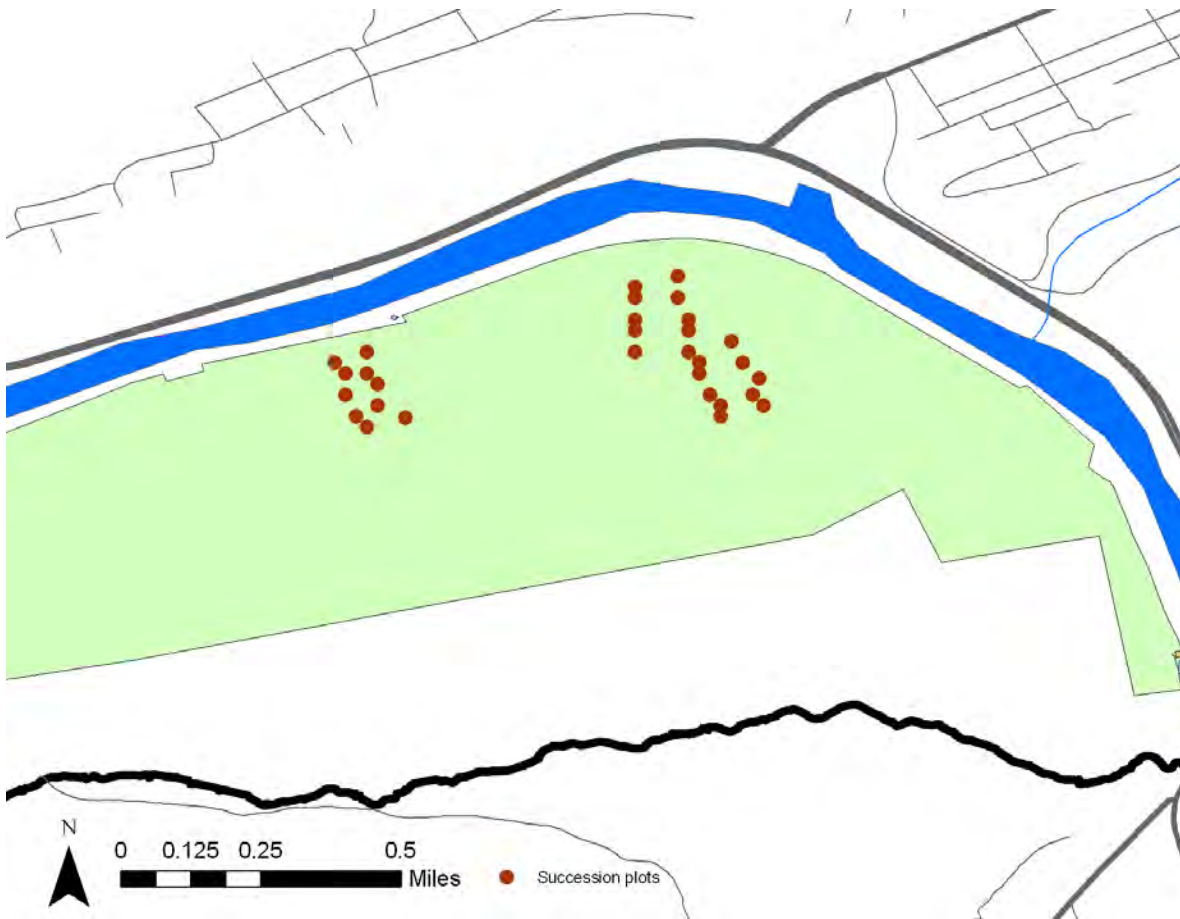
### Succession Monitoring

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).

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,

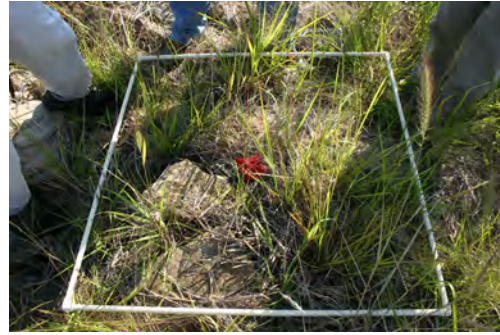
100 and 150 meters respectively. The GPS coordinates of the posts were recorded and are found in the report (Appendix H-1).



**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.<sup>3</sup> 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?

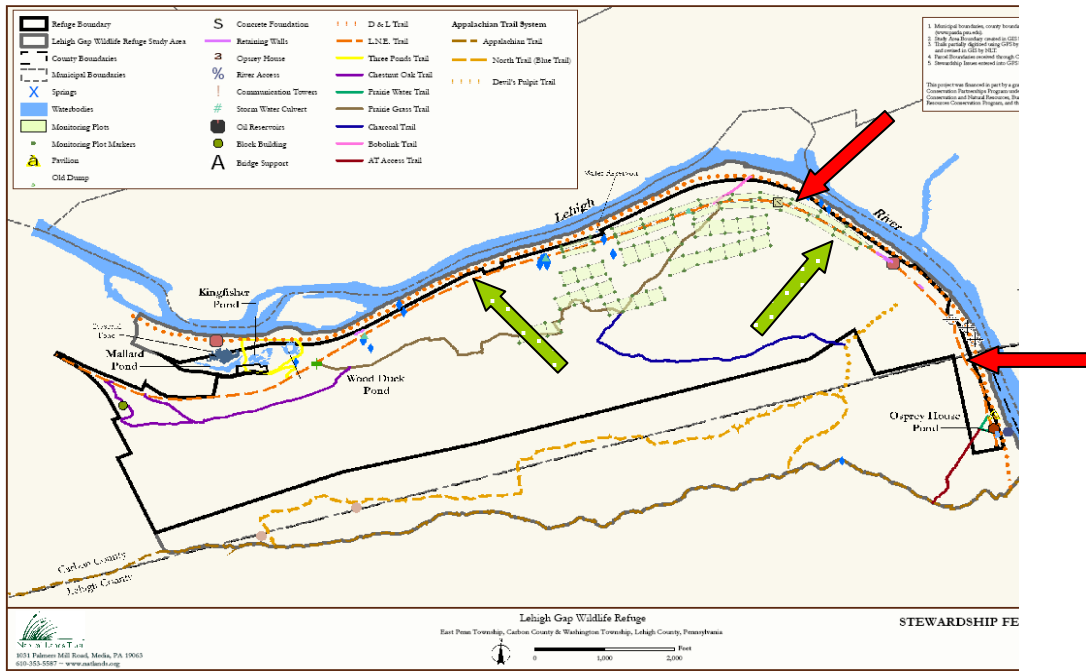


A summary of this research is presented in poster format in Appendix G. This poster was accepted for presentation at the 2009 National Conferences on Undergraduate Research held at the University of Wisconsin, LaCrosse and was selected for the Council on Undergraduate Research Posters on the Hill Event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

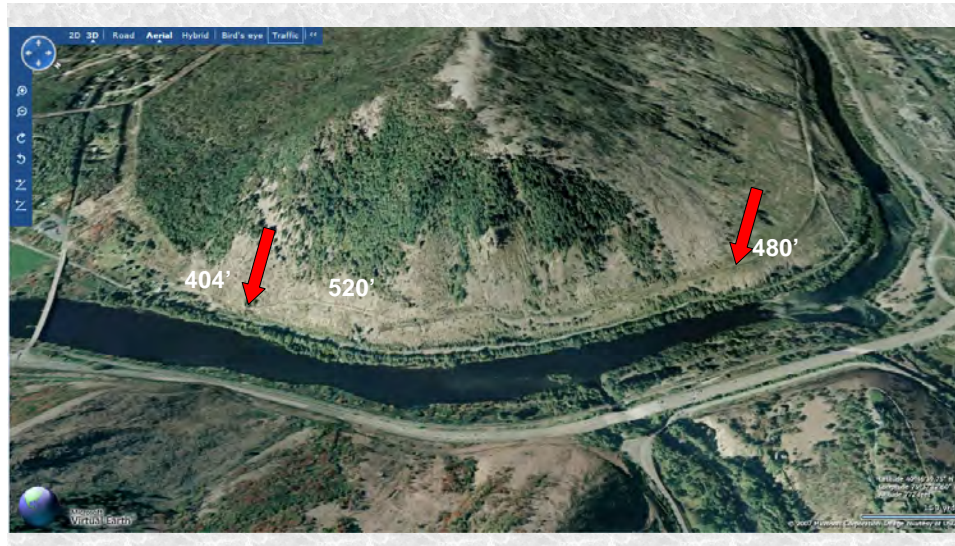
The map on the following page shows the areas in which plant samples were obtained. Except for sandwort, samples were taken from plants growing along the LNE trail between the red arrows (2007). Sandwort samples were taken from populations growing within the grasslands in the area between the green arrows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

---

<sup>3</sup> 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.<sup>4</sup> 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 senescence 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.<sup>5</sup>

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<sup>2</sup> 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.).<sup>6</sup> 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

---

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

---

<sup>5</sup> 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.

<sup>6</sup> 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**

| <b>Plants sampled</b>             | <b>Leaf zinc levels from LGWR studies (2007-08)</b> | <b>Literature values for zinc levels in plants within the Palmerton Superfund site*</b> | <b>Levels of observed plant stress</b> |
|-----------------------------------|-----------------------------------------------------|-----------------------------------------------------------------------------------------|----------------------------------------|
|                                   | <b>ppm</b>                                          | <b>ppm</b>                                                                              |                                        |
| <b><i>Tree species</i></b>        |                                                     |                                                                                         |                                        |
| 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                               |
| <b><i>Other plant species</i></b> |                                                     |                                                                                         |                                        |
| 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.<sup>7</sup> 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

---

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

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 folivory, nectarivory/pollination, and seed predation.<sup>8</sup> 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).<sup>7</sup>

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

---

<sup>8</sup> 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<sub>4</sub> photosynthetic pathway which produces different proportions of the stable isotopes <sup>12</sup>C and <sup>13</sup>C than the C<sub>3</sub> 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 <sup>13</sup>C to <sup>12</sup>C than organisms that consume trees, shrubs, forbs, and grasses with the C<sub>3</sub> pathway. Organisms that consume tissue from both groups will have isotopic ratios that are intermediate between the ratio for C<sub>4</sub> plants and that for C<sub>3</sub> 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<sub>3</sub> 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<sub>4</sub> 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

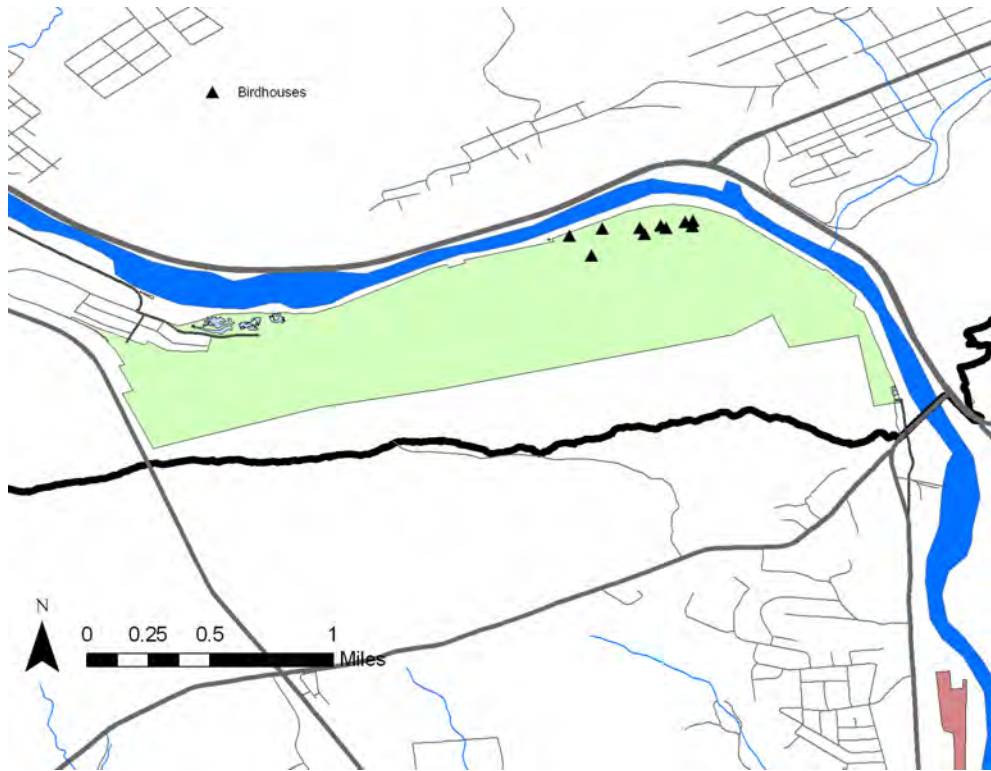
for Blue Grosbeak (*Passerina caerulea*)  
in Carbon County (see Chapter 5).



**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 1<sup>st</sup>.)



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



## *Chapter 10*

# *The Physical Environment and Risk Assessment*

## *Studies of the Physical Environment*

The abiotic (non-living) factors are important in determining the types and numbers of organisms that exist in that environment. When the soil, water, or atmosphere in a particular environment is contaminated, the impact can be dramatic due to the toxicity effects directly on a particular species or indirectly by impacting some aspect of habitat or the food chain. This, of course, is the case with the Lehigh Gap Wildlife Refuge – contaminated both by acid deposition and heavy metals both of which are harmful to plants and animals. In addition, in areas that were devoid of vegetation, there is little protection from intense sunlight or wind (other abiotic factors) that may also cause harm to plants and animals. Not related to the industrial factors that influenced the Refuge, the potential for climate change to alter habitat and ecosystem functions is significant. For these reasons, it is important for the LGNC and its partners to monitor and study abiotic factors including the distribution and persistence of the heavy metals in the region of the former zinc smelters, microclimates at the site, and long term patterns in temperature, wind, and precipitation.

### **Airfall of metals from the Palmerton, PA, zinc plant: Distribution and preservation**

The stacks of the NJ Zinc Co. created airfall deposits throughout the 20th century in the region surrounding Palmerton, PA. The deposition of zinc,

cadmium, lead, and arsenic, led to the destruction of a forest ecosystem along the neighboring Kittatinny Ridge and metals contamination in the town and surrounding area. Although the West Plant was closed in 1980, and primary smelting ceased at the East Plant that year as well, concerns linger over whether the soil remains contaminated with elevated levels of smelter-derived metals. The present concentration and distribution of metals in the soil is the result of the initial (20th century) concentration and the processes of leaching, erosion, and biological uptake and dispersal that have proceeded since the smelter was shut down. Drs. Dork Sahagian and Steve Peters of Lehigh University spearheaded a study that analyzes the current distribution of the metals in the region. Other members of the research team from the Lehigh Earth Observatory and department of Earth and Environmental Sciences included George Yasko, Jennifer Lofaro, Jill Burrows, Johanna Blake, and Kevin Smith.

This study was funded by the US EPA Brownfields program to determine the extent of contamination of soils in the surrounding "far-field" regions outside the superfund site. The Lehigh group also explored the metals concentrations in the soils of the West Plant itself, as this was excluded from the CERCLA process, so it can be investigated as a Brownfield. While much of this study was not conducted at the Refuge, persistent



contamination in the region can impact wildlife that does not recognize property boundaries, plant materials (falling leaves, dispersed seeds, etc.) that can carry contamination to new places, and movement of the contamination through ground water and surface water. The Lehigh team members have been active participants in the LGNC Research Roundtable and provided input into this assessment, especially in the production of new maps since they were doing GIS work as a part of their study.



**The West Plant Site (yellow) and the Lehigh Gap Wildlife Refuge (green)**

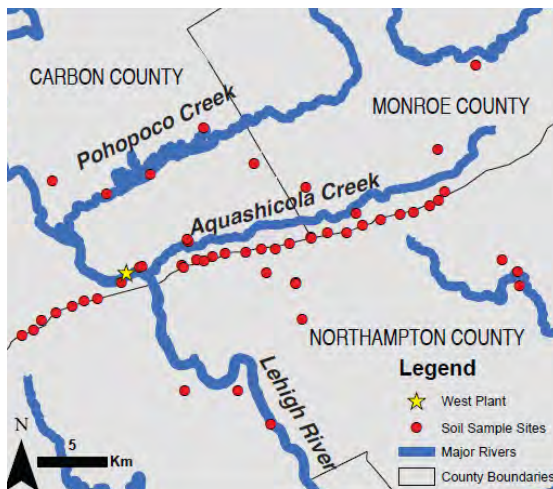
Key questions considered in this regional study included:

1. What is the regional extent of contamination by smelter-derived metals in the Palmerton region? What are soil metal concentrations throughout the region? What are metal concentrations in local waters, plants, and animals? What is the regional extent of environmental concern regarding contamination?

2. How does vegetation affect water flux out of the soil and thus metal flux in the subsurface?
3. How do different vegetation types affect metal mobility out of the soil and into the human environment?
4. What is the flux of metals into the Lehigh River through ground water transport? What is the fate of these metals after they enter the river?
5. What types of plants are most and least successful in metal-contaminated soil environments? How do these compare to existing planted grasses and other landscaping around homes, business, and parks throughout the region?
6. How can the public be better informed regarding actual levels of contamination of soils and water, and how they can best minimize metals uptake on their properties?
7. How can the Palmerton region be used as a model for remediation of metal contamination at other sites throughout the country?

At the site of the smelter, analyses of samples from 141 shallow soil pits had zinc concentrations up to 95 mg/kg, with a mean value of 14 mg/kg. Lead concentrations in the same soils had concentrations ranging up to 250 mg/kg, with a mean value of 72 mg/kg.

The Lehigh team has now sampled a suite of soils from the "far field" region up to 25 km away from the smelter site to determine the spatial extent of remaining metals contamination. Soil pits were dug and samples collected from the shallow O-horizon, the underlying A horizon (typically 2-4 cm depth), and the B-horizon at about 20-30 cm to determine not only the geographic distributions of metals, but also the depths at which these different metals are now found in the subsurface.



**Regional soil sampling locations**

Key findings from these studies:

- Concentrations of zinc and cadmium decrease with distance from the West Plant and metal concentrations to the east of the West Plant are higher than to the west consistent with the prevailing wind in that area.
- Lead levels do not decline with distance from the smelter indicating that there is likely an additional source of lead contamination.
- Significant concentrations of metals are still found in the soil at the Refuge property.
- Zinc is primarily in the shallow layer of soil, suggesting that plants in this layer take up zinc and release it through decomposition, perpetually keeping higher levels of zinc in the top most layer of soil.
- After rain events, there is an increase of zinc and cadmium concentrations as the discharge of the springs (Railroad, Smilax and Hidden Springs, see map above) increases. However, the concentrations of these contaminants found in the water at LGWR are small, and concentrations of all metal contaminants are well below US EPA drinking water standards.
- Low concentrations of contaminants seen in the water at LGWR also indicate that, while soil samples were found to have significant concentrations of metals, they are not very mobile and are not a significant source of metals to the Lehigh River.
- A decrease in pH of soils and groundwater is highly likely within Lehigh Gap Nature Center due to the acidity of precipitation; the pH of precipitation will continue to decrease with rising atmospheric CO<sub>2</sub> levels. Plants also secrete organic acids which can lower soil pH.
- According to a model from this study, a decrease in soil pH by as

little as 0.5 could result in a 50% decrease in the mole fraction of zinc that remains adsorbed to soil particles (i.e. the contaminant zinc in the soil is solubilized and has increased bioavailability).

- Samples from springs at the Refuge were found to contain no alkalinity, lowering the ability of these systems to buffer a change in pH.
- Zinc concentrations in the Lehigh River are influenced by run-off and groundwater from the West Plant industrial site and the lands surrounding Aquashicola Creek which flows into the Lehigh River.

Additional details of the Lehigh project are included as appendices:

- Appendix K-1: A technical report entitled: **Report on Lehigh University Research Activity in the Palmerton Region from 2005-2010.**
- Appendix K-2: A research poster entitled ***“Assessment of Zinc, Arsenic, Cadmium, and Lead in the Environment Surrounding Palmerton, PA”***
- Appendix K-3: An educational pamphlet entitled ***“Assessment of Metals in the Environment Near Palmerton, PA”***

This research also resulted in two master theses:

***“The fluxes and transport mechanisms of groundwater and***

***surface water contaminants (Zn, Pb, Cd, As, and Cr) into a fluvial system: Palmerton, PA”***

Johanna M.T. Blake  
M.S. in Earth and Environmental Sciences  
Lehigh University  
April 30, 2010

***“Assessment of Natural Attenuation of Arsenic, Cadmium, Lead and Zinc Using Hydrograph Separation”***

Jill E. Burrows  
M.S. in Earth and Environmental Sciences  
Lehigh University  
April 30, 2010

The far field data distribution can provide information for local communities regarding soils chemistry and help to guide land use practices within residential, business, and agricultural properties throughout the region. Concerns regarding contamination from metals airfall have played a role in depressing local economies, further exacerbating and perpetuating the economic impact of the closure of the smelter itself. These analyses can potentially ameliorate such concerns by providing the actual distribution and concentrations of metals in the region surrounding Palmerton.

### **Other Risk Assessment Studies**

As part of the ongoing monitoring and risk assessment of the Palmerton Superfund Site, the springs on Refuge

property were also monitored by Arcadis staff in October 2007 and May 2008. The springs were analyzed for pH, conductivity, turbidity, dissolved oxygen, temperature, salinity and estimated flow.

Scientists from the U.S. Geological Survey and Columbia Environmental Research Center (John M. Besser, Bill Brumbaugh, and Chris Ingersoll) prepared a presentation for the Palmerton Zinc Site Natural Resources Stakeholders on June 5, 2009 entitled *Ecotoxicology studies with sediment, pore water, and surface water from the Palmerton Zinc site*. The objective of this study was to update the findings of a 1997 study. Samples were collected in August 2008 to document current levels of metal concentrations and associated toxicity in stream water, sediment, and sediment pore water at sites in Aquashicola Creek (including an uncontaminated tributary, Buckwha Creek), and Lehigh River.

The U.S. Fish and Wildlife Service (along with multiple state and federal agencies as partners) have produced Fact Sheets on various ongoing studies related to the Palmerton Superfund Site. These studies are part of the Natural Resource Damage Assessment (NRDA). Fact sheets include Aquatic Investigations: *Evaluation of Injury to Aquatic Habitat Resulting from Metals Contamination*— a study which examined macroinvertebrates, periphyton (algae, bacteria, and fungi attached to the stream bottom) and fish communities; Forest Investigations: *Evaluation of Injury to Forest Habitat Resulting from Metal Contaminated Soils*; and an Appalachian Trail Hiking

Study: *Assessment of Hiking Activity in Areas Potentially Impacted by Contamination*.

Studies for previously mentioned risk assessment reports and the EPA five-year review reports are aimed at constantly reviewing the human and environmental risk associated with this Superfund site.

## Soil

As part of the recommended monitoring goals, the EPA has indicated that metals monitoring should include the determination of soil metal concentrations from soil composites from the A Horizon (personal communication with EPA staff). The Lehigh University project contributes important information as have other studies.<sup>1</sup>

Since the long-term success of plant growth is intimately linked to soil characteristics, the EPA monitoring recommendations also include further analysis of soil characteristics including:

- Amendment/soil depth – to assess whether soil structure is developing;
- Organic material in surface soil –

---

<sup>1</sup> 2007. [Data Report for the Scoping Study on Metal Contaminant Levels in Forest Soils and Concurrent Habitat Evaluation for the Palmerton Zinc Natural Resource Damage Assessment, Palmerton, Pennsylvania](#), The Palmerton Natural Resource Trustee Council; and Anonymous. 2004. Preliminary Human Health and Ecological Risk Evaluation and Data Summary Report – Warm Season Grass Remediation Area. BBL, Inc., Annapolis MD.

to assess conversion of plant matter to soil which is an indirect assessment of soil biota health;

- Soil pH – to assess acidification over time as lime amendment degrades and the impact of ongoing acidic deposition from precipitation;
- Nutrient composition (N, K, P) – to determine if plant requirements are met;
- Micronutrient composition (Fe, S, Mg, etc.) – to determine if plant requirements are met; and
- Microbial respiration and microbial community composition – a biotic indicator of soil health and to determine the success of inoculants

Besides its critical role in supporting growth of the primary producers and hosting decomposers, soil is increasingly being recognized for its importance in carbon acquisition and sequestration. Disturbance (removal) of vegetation from soil – be it in forests or coastal wetlands, increases the rate of carbon release into the atmosphere. Theoretically, restoration of vegetation to a denuded area should help to not only capture carbon, but help maintain carbon in the soil.<sup>2</sup>

---

<sup>2</sup> See for example, Lal, R. 2004 Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. *Science* 304: 1623-1627; 2009. [Blue Carbon Report](#), UNEP and Soil Carbon Research information from the Rodale Institute

### Microclimate at LGWR

Impending global climate change will typically impact specific regions by changing the temporal and spatial weather patterns (i.e. climate) of temperature, wind, and precipitation. While scientists have predicted changes in global and regional average conditions, there have also been predictions for changes in weather extremes and weather variability. Ecosystems are likely to be impacted at multiple scales. Significant microclimate variations in temperature, wind, and moisture are known to occur on spatial scales of meters to kilometers, both horizontally and vertically and on temporal scales ranging from seconds for wind vortex cycles to diurnal for solar and infrared flux, to weekly and seasonal for changes in insolation and air mass properties. Less well studied are interactions among microclimate, vegetation, and soil properties: each can influence the others over time.

One ecological pattern predicted to occur in response to global climate change is the shift toward higher latitudes and higher elevations of current climate-dependent species ranges and biome boundaries because of changes in average or extreme weather conditions. The LGWR is an ideal place to study such changes and to become part of a larger network of ecological observatories because it straddles an important biogeographic feature, the Kittatinny Ridge. The SW-

---

<http://www.rodaleinstitute.org/20090716/gw2>



to-NE trending ridge with roughly 1000-foot elevation relief, together with the Lehigh Gap through which the Lehigh River flows, create extreme variations in spatial and temporal microclimate. The previous loss of vegetation and soil caused by heavy metal pollution together with the recent experimental restoration of grasslands and the existence of legacy forest patches (especially on the southern slopes) provide an opportunity to document current and future microclimate-vegetation interactions while also exploring the impact of microclimate on restoration efforts. In short, microclimate variations are expected throughout the Refuge because of its steep topography, variations in vegetation cover and soils, and location near the Lehigh Gap along the Kittatinny Ridge. Microclimate can influence all types of wildlife including the potential for colonization of new organisms.

To characterize the LGWR microclimate a network of weather stations (three sites) and supplemental sensors (at the station sites plus 3-6 other sites) has been installed. Funds from the WRCF of the DCNR, supplemented by a grant from the U.S. Dept. of Education, supported this project. The network was designed and installed by Dr. Bruce Hargreaves of Lehigh University, with help from a number of LGNC interns. It provides broad spatial coverage of LGWR at high temporal resolution. The Davis Instruments Vantage Pro2 system of stations and sensors was chosen based on its low cost for solar-powered wireless sensors combined with its ability to create extended radio networks using multiple radio

repeaters equipped with Yagi antennas.

The current network of weather stations and satellite sensors (installation began in February 2009 and was completed in July 2009) continuously record spatial patterns from ridge to river at a temporal resolution of 5 minutes. The 3 weather stations record air temperature, wind speed and direction, humidity, precipitation, and leaf wetness at 2m above ground, plus soil temperature just below the surface. Three satellite stations record a subset (air temperature, humidity, leaf wetness, also at 2m above ground, plus soil Temperature) at 3 other sites. One weather station also records solar radiation (broadband incoming radiation and UV-B radiation). Station consoles also record barometric pressure at the base station in the Osprey House (see maps on pages 10-9 to 10-10). All sensors are connected by a radio network and data are automatically stored on local computers, archived, and graphs of 24-hour patterns are automatically sent to a web site.<sup>3</sup> Data is also shown on the LGNC website.<sup>4</sup> A combined database will be designed to facilitate analysis and web dissemination of all data.

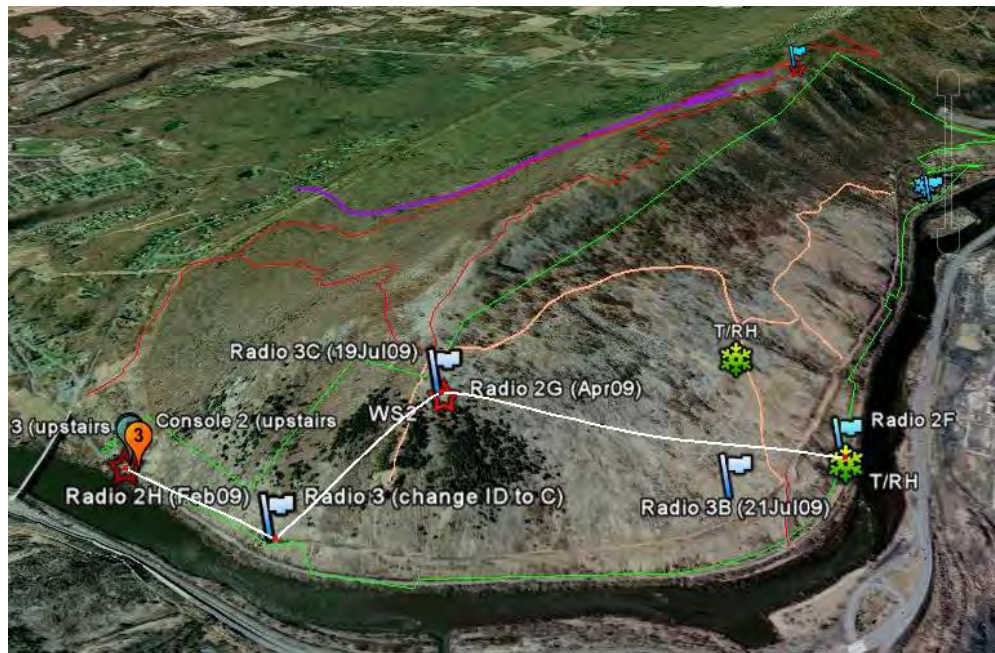
---

<sup>3</sup> See <http://www.lehigh.edu/~brh0/LGNC/>.

<sup>4</sup> <http://lgnc.org/resources/weather>



**Overview of LGWR microclimate network (24 July 09)**  
Flag=repeater radio, star=weather station, snowflake=T/RH station



**LGWR microclimate network 2, view from NE (24 July 09)**  
Flag=repeater radio, star=weather station, snowflake=T/RH station, green line=LGWR boundary, red=AT, white line=radio path

Distinct patterns are evident already for elevational and along-river gradients in temperature, humidity, dew point temperature, precipitation, leaf wetness, including periodic night density flows of cool air (up to 15°F difference) from high to low elevation when the sky is clear and wind is light. There is a tendency for somewhat higher precipitation and cooler air temperature on average at the higher elevation. Surprisingly, there was little correlation between wind speed on the ridge and wind speed on the deck of the Osprey House.

A proposed expansion of this microclimate network will allow for four sets of paired measurements at 2-3 m and at 0.5m above ground to capture the impact of vegetation on the fine scale atmospheric boundary layer and will add soil moisture measurements (at 1-2 depths) at 4-8 sites for a semi-quantitative index of the interactions of vegetation, soil, and microclimate. It is proposed that a fourth weather station and paired satellite station be added in the grassland restoration area. The rationale for horizontal sensor placement is to cover vegetation patterns and topographic variation by our horizontal choice of sites (forest on south slope, elevation impact on ridge with two sites to account for proximity of Lehigh Gap, grassland restoration, northern exposure, and non-restored land cover on north slope). The rationale for simultaneous paired measurements at 0.5 and 2-3 m above ground is to capture the effects of vegetation on the boundary layer while accounting for the extreme topographic variations.

With the weather/microclimate monitoring system in place, the LGNC with its partners have begun a long-term

record of microclimate variations. Temperature and moisture differences across the elevation range of LGWR caused by the atmospheric lapse rate and wind-ridge interactions should be observed. It is being determined whether the instruments allow researchers to examine boundary layer consequences on vegetation growth (in terms of a scale of feet and inches of vegetation height rather than the kilometer scale of atmospheric science). The effect of re-vegetation efforts on surface conditions over time and space might also be possible to study. As noted by John Dickerson, the seed rain over the decades had no success in establishing native vegetation on the mountainside. However, within 1 to 2 years after the grass was planted the recruitment came on rapidly. The fastest change to the physical environment (due to the grass presence) was likely to temperatures, air movement and humidity at the surface, ameliorating these factors enough to allow for seed germination. Short and long-term weather data will also be important as the LGNC begins phenology monitoring. This resource should help to further our understanding of ecological response and adaptation to climate change on the Kittatinny Ridge at Lehigh Gap.

### **The LGWR Physical Environment and Education**

As with other aspects of the ongoing research at the Refuge, the LGNC and its partners are continually finding ways to link research and education. The weather stations described above are just one example. Major aspects of the physical environment at the Refuge are the unique geological



features (which also create some of the challenges for restoration work). State geologists from Pennsylvania have been to the site and have helped to develop geology-based field exercises for K-12 students and helped to run a workshop for teachers and the public. Some of the resources they provided led to an article in the *Wildlife Activist*, the LGNC publication.

A unique project entitled “Engagement in Science and Media Literacy: Sixth Graders Solving Problems and Researchers Listening” run by Andrea J. Harmer, Director of Web-based Education at Lehigh University involved the LGNC and presented at the May 2009 LGNC Research Roundtable. This project was a three-year, research program that engaged sixth-grade students in the authentic, environmental and health concerns resulting from the 83 years of zinc smelting activities at the Palmerton Superfund Site. Students chose soil and plant samples from the Site and were provided with the opportunity to remotely operate a scanning electron microscope from their sixth grade classroom. The students researched current EPA solutions to remediate the polluted site, which includes various attempts at re-vegetation, and further studied a new, university-based technique that includes using iron nanoparticles to neutralize heavy metal toxins in other polluted areas. A central question in this project was “What happens when middle school students and university faculty join forces to try and solve a community, environmental problem using the latest techniques in scanning electron microscopy and nanotechnology?” The answer was

that real time, engaging, learning takes place for both parties involved.

Designed to foster learner engagement, this method used an online, problem-based, science inquiry that investigated the Lehigh Gap, Palmerton Superfund Site during five weeks of collaborative classroom sessions. The inquiry prototype was authored in *WISE*, the Web-Based Science Inquiry Environment headquartered at UC, Berkeley. Online materials, readings, and class sessions were augmented with the remote access to an electron microscope to analyze Lehigh Gap samples. An introduction to nanoscale science and nanotechnology through the *ImagiNations* Web site at Lehigh University was also used. Students contributed the artifacts they generated during their research to a university database and presented them to researchers at the university working on the same problem. This approach proved highly engaging and generated design and development guidelines useful to others interested in designing for student engagement and introducing nanoscale science and electron microscopy in middle school science.

This study further found that students’ engaged in science inquiry both behaviorally and emotionally and on several different levels. The various levels appeared to create two hierarchies of engagement, one based on behavioral criteria and the other based on emotional criteria. It was found that five factors most prominently contributed to the students’ engagement; cutting-edge technology, creative freedom,

collaboration with scientists working on the same problem, contribution to the problem solution, and communication of the students' results outside of the classroom.

Finally, at the 2009 LGNC Research Roundtable, the entire group of participants was educated on the history of the zinc smelting operations and a 1980 National Cancer Institute study by Dr. Patricia Bradt of Muhlenberg College.



## *Chapter 11*

# *Addressing the Hazards and Recommendations from the LGWR Ecological Assessment – Part I*



# *Update on Hazards and Previous Recommendations*

A number of hazards and risks were identified in Part I of the Ecological Assessment for the Refuge. In addition, several management recommendations were made. An update on the status of the associated recommendations is provided below.

## **- Soil Contamination and Erosion Recommendations** (p. 44 of the Ecological Assessment – Part I)

- ***Perform soil test to determine the extent of the contamination:*** As described above, soil testing has been done by Lehigh and by independent environmental firms as part of the NRDA.
- ***Test water resources within the Refuge:*** The water resources have also been tested through the various studies described above and in the macroinvertebrate studies described in Chapter 7.
- ***Determine whether any of the metals in the soil pose a risk of inhalation, ingestion or absorption by Refuge visitors:*** Based on risk assessment studies that have been completed, the EPA believes risk is below any threshold that would require procedures concerning visitors pursuing passive recreation. Even risk to workers is extremely low. Common sense procedures such as washing hands and removing mud from boots are all that are required for workers. Visitors are at far less risk than workers at the site. (Charlie Root, personal communication)
- ***Continue the process of establishing native warm-season grasses and other native meadow plants on exposed areas to stabilize soil resources*** – see Chapters 8 and 9.

## **- Hazards Recommendations** (p. 45)

- ***Secure or remove the block building near Lehigh Tunnel:*** This building was secured in 2009. It was filled in to ground level with soil and rocks. The tank is covered and no one can fall into the structure and be injured.
- ***Determine which structures have historical significance; remove if not historic or educational:*** The Tannery building has been temporarily stabilized and a significant amount of work has been done on the Osprey House. Additional renovations are planned. Other structures related to the former railroads have both historical significance to the site and educational value so they remain.
- ***Secure oil lamp reservoirs and storm water culverts:*** Oil lamps have been filled with rocks to prevent entry and culvert secured by stand-pipe.

- ***Remove/repair retaining walls:*** Most retaining walls are in good repair. The cribbing along LNE rail bed is in disrepair but removal could jeopardize stability of trail. This also has historic educational value. Warning signs (“Danger! Keep off”) have been installed.
- ***Remove old railroad ties and telephone poles:*** Most of the ties have been removed but most of the poles remain. Some of these used as posts for nest boxes and some are transect markers for various studies. At this point, they do not seem to pose any risk.
- ***Investigate what is under the concrete cap between Mallard and Kingfisher pond:*** This has not been done, but seems to pose no risk.

- **Native Grassland recommendations** (p.46)

- ***Educate the National Park Service about significance of ridge top grassland:*** The LGNC has done this and the NPS no longer plans to try to forest the area or build an access road.
- ***Explore land swaps with National Park Service and PA Game Commission to gain control of ridge top grassland for its perpetuation:*** This is no longer needed, since they no longer plan to destroy this area with a road
- ***Together with the Pennsylvania Game Commission, develop a grassland management program for the ridge top savanna:*** There has been no action on this to date; this should be a long-term goal.
- ***Design re-vegetation program on lower slopes to avoid interference with ridge-top grassland:*** To the extent possible, this was done. Collection of local ecotypes was impractical for the volume we needed but PA ecotypes were used whenever possible. The need for erosion control outweighed this concern, so commercially available seed was purchased to speed the re-vegetation process. A 100 foot buffer was left between any re-vegetation work and the savanna.

- **Invasive Plant Recommendations** (p. 50)

- ***Develop an invasive plant management plan*** – See Chapters 8 and 9; Arcadis staff members have developed a plan.<sup>1</sup>
- ***Focus initial control efforts within natural communities*** (e.g. in riparian area and wetlands): See Chapters 8 & 9; no specific funds have become available for invasive species management to date beyond those provided by CBS Operations under CERCLA. Invasive plant species are now also appearing in the grasslands, so

---

<sup>1</sup> Lansing, J. and K. Romaine. 2007. Draft Invasive Plant Management Plan, Operable Unit 1, Geographic Area 2. Arcadis BBL, Albany, NY.

management options for this area of the Refuge must be discussed. To date, prescribed burns and mass grazing have been discussed with outside consultants. Discussions with the scientists from Fort Indiantown Gap about prescribed burns was discussed in Chapter 6 as it relates to habitat management for the Regal Fritillary and D. Kunkle has had discussions of mass grazing with Jerry Brunetti of Agri-Dynamics. With respect to the latter, it is unlikely that livestock owners would want their animals grazing on land contaminated with heavy metals, even if the toxicity risk is determined to be low.

- ***Address invasives along old rail beds:*** This has been done by the LGNC interns and will continue to be monitored.

- **White-tailed deer recommendations** (p. 52)

- ***Undertake a monitoring program:*** This is being done through the grassland enhancement/deer exclosure study and through a pilot mammal survey that includes trail cameras.
- ***Develop a deer management program:*** This will be developed after results are in from the monitoring studies.
- ***Start a research and education program concerning deer, including demonstration deer exclosures:*** The exclosures have been installed and the research is being conducted. There is informational signage at the exclosure site, but additional public programming could be developed since deer management is a state-wide issue.

- **Trash and Debris recommendations** (p. 53)

- ***Clean up scattered trash:*** This has been done and but is an ongoing process. Signs indicate that the Refuge is a trash-free park.
- ***Remove non-organic debris from dump:*** This is along LNE Trail near the Three-ponds Trail sign; plans are to cover this with fill, since removal would be difficult and expensive.
- ***Organize clean-up days:*** These occur twice annually in March and August. Numerous LGNC volunteers participate in the events.

- **Graffiti recommendations** (p. 54)

- ***Remove graffiti with environmentally safe cleaners:*** These were tried, but did not work. Volunteers and interns tried chipping the graffiti off with hammers. The LGNC resorted to painting over the most visible or any new graffiti and are allowing the old graffiti to remain for now.

- **Monitor and address new events:** See previous comment.

**- Property boundary recommendations (p. 54)**

- **Confirm property boundaries and survey and post as needed:** No surveys have been needed because most boundaries are with other government agency lands and those with private landowners are not in dispute. If any disputes arise, surveys can be done, but the cost is prohibitive if there is no question of ownership. Posting has been completed where needed, however needs to be monitored and re-posted as necessary. Posting is not needed between boundaries with the Pennsylvania Game Commission and National Park Service properties, Lehigh County, or East Penn Township.
- **Investigate acquisition potential for in-holding at ponds:** The owner is not willing to sell at this time. He did offer sale of the property and we began fundraising, however, he changed his mind, refused to sell, and we forfeited the grant we had obtained to help with the purchase. The LGNC is looking at other potential properties, but funding for land acquisition is a problem.

**- Railroad Bed Recommendations (p. 55)**

- **Engage a structural engineer to provide the maintenance and capital replacement estimates for the support and drainage structures associated with the railroad beds:** Several grant requests concerning this have been rejected. Interns have built erosion control structures with rocks from the site that have stabilized the bed.
- **Develop a maintenance schedule and capital replacement strategy:** See comment above.
- **Determine historical or educational significance of remaining railroad structures:** The LGNC believes that the remaining structures have both historical and educational value for the site.

**- Secondary Education Recommendations (p. 56)**

- **Inform local school districts of the Refuge and its educational opportunities:** Educational programming is a strength of the LGNC, not just for secondary education levels but for K-12 students, undergraduate students and graduate students. As noted in the Introduction, over 2000 students were served during the 2009-2010 school year in LGNC educational programs. Students from nine different colleges participated in class trips, presentations, or research opportunities at the LGWR property. Special programs for high school students like the Service Learning in Public Policy program are using the Refuge. With the construction of the new Visitors' Center and Education Building and the addition of educational signage, even more opportunities are available.



- ***Recruit and maintain contact with interested teachers in those districts:*** For the past four years, LGNC and Moravian College have collaborated to provide Act 48 in-service training for teachers from Northampton, Lehigh and Carbon Counties. These workshops are designed to not only provide opportunities for K-12 teachers to learn about ecology, environmental science and natural history, but also to encourage them to use the Refuge as an outdoor classroom. A small, but regular, core of teachers from private and public schools have repeatedly participated and incorporated ideas into their curriculum – many of which have direct ties to the Refuge and the story of the Superfund site and restoration project. In addition, LGNC staff has worked with more than 20 teachers from various surrounding districts to design custom field trips to meet the needs of their students.

- **University Research and Education Recommendations** (p. 57)

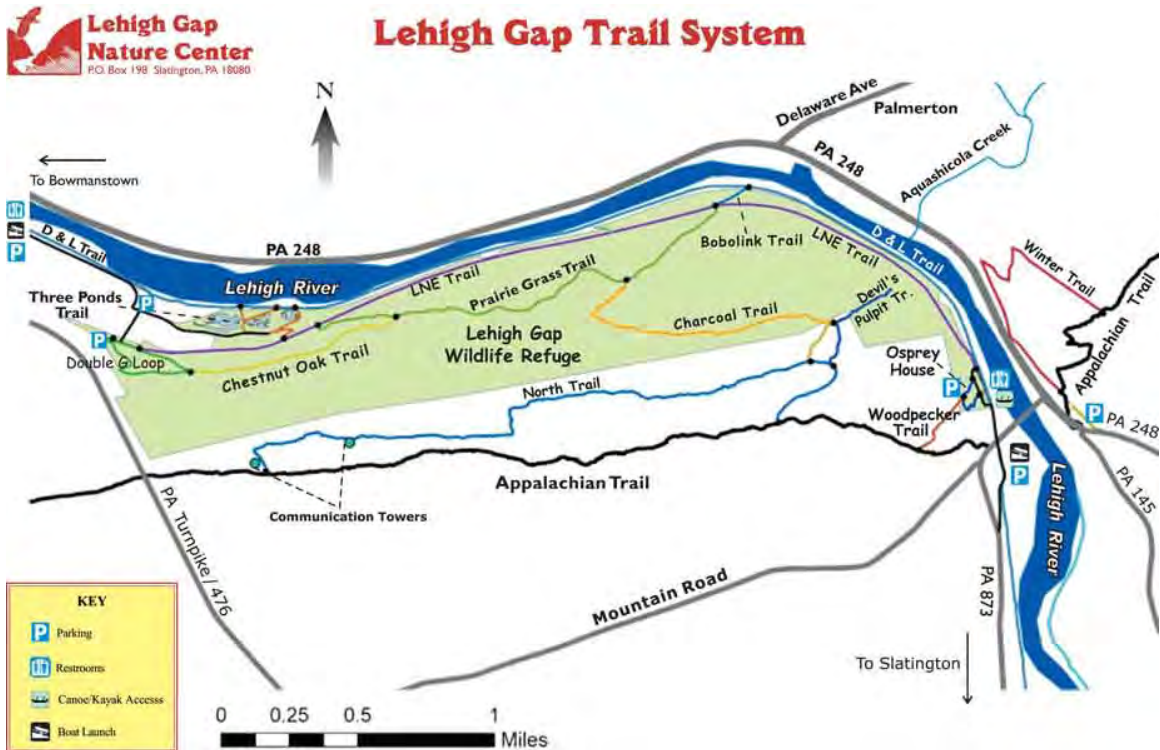
- ***Continue established research and education programs with local colleges and universities:*** As should be evident from this assessment, this has occurred. Over the past six years, LGNC has provided paid internships in ecology and wildlife research for 18 students and many students and faculty have participated in research at the Refuge as described in this report (see Appendix A). A second Research Roundtable was convened in 2009 and the list of participating institutions has expanded since Part I of the assessment was written.
- ***Inform other regional colleges and universities of the research and educational opportunities of the Refuge:*** See above. The restoration work has received state and national recognition, so that there have been visitors, including researchers, from other states and even from other countries. A number of presentations have also been made at academic institutions, scientific conferences at the regional, national and international level.
- ***Maintain contact with interested faculty:*** This has been done through the Research Roundtable, ongoing communication with the researchers with ongoing projects at the Refuge, and related meetings about regional watersheds and conservation initiatives.

- **Walking Trail Recommendations** (p. 58)

- ***Monitor trails regularly:*** This is done.
- ***Work with the D & L National Heritage Corridor to restore railroad bed as a walking and biking trail:*** This is done in the Lehigh County section and the LGNC and D & L have been working with East Penn Township to finish the improvements in the section of the trail in Carbon County. The entire trail bordering Lehigh Gap Wildlife Refuge is scheduled to be completed by June 2011.
- ***Determine if any species of concern are affected by existing trails:*** To our

knowledge this is not a problem. But, as noted earlier in the report, increased use of the Refuge for passive recreation could create problems in the future. Routine monitoring and trail work is done by volunteers from the Allentown Hiking Club and LGNC.

- Minimize future trails to minimize adverse effects on wildlife and sensitive plant species:** The location of trails has been carefully thought out. Descriptions and the new trail map are available at the LGNC website: <http://lgnc.org/maps-directions/trail-maps>. The trail map is also shown below. The LGNC mission includes both conservation and recreation with public education about nature, the restoration project, the history of the region, and conservation being integrated in to both activities. It is not desirable to exclude people from the site; there is too much to see and learn about. Thus, we must include education about stewardship and diligently monitor areas that get a lot of use.



**- River Access Recommendations (p. 59)**

- Engage township, D & L National Heritage Corridor and user groups to help monitor areas for unwarranted use.** See below.
- Monitor access to prevent environmental degradation; move or improve access points as needed.** The LGNC has worked with a number of partners, most notably the townships on the issue of river access. As shown on the trail map on the previous page, two boat launches—one on either side of the Refuge—have been

built. The one downstream of the Refuge on the former Pfizer property was completed in fall 2010. It is believed that these are assets to the Refuge and may decrease use of the canoe and kayak launch site on the Refuge property. Many of the visitors to the LGWR arrive by water and routinely stop to ask volunteers about the site, including the gardens. This provides yet another way to educate people about the LGNC projects.

- **Hawk Watching Recommendations** (p. 60)

- ***Determine the extent of hawk watching preferred on the Refuge:*** The best vantage points for observing raptor migrations are at the top of the Kittatinny Ridge which is a significant (but enjoyable) hike from the LGWR parking area. It is easier to access good raptor viewing sites at Bake Oven Knob. The LGNC just celebrated the 50<sup>th</sup> year of the Bake Oven Knob Hawk Watch. The annual Hawk Fest has been expanded to a migration festival that takes place at both the Refuge and Bake Oven Knob (BOK). For study and educational purposes, BOK remains the better site, although monitoring of kestrel populations and breeding is being monitored at the Refuge. Raptors, including bald eagles and ospreys are seen flying over the Lehigh River from the railroad bed trails and from the grasslands of LGWR; these are exciting surprises to LGNC visitors who are often only (at best) casually interested in birds.
- ***Explore collaborative research with Pennsylvania Audubon and Hawk Mountain Sanctuary:*** The LGNC is partnering with these organizations due to a common interest in bird and bird habitat conservation. Recently, LGNC has initiated a new multi-organization partnership (including Pennsylvania Audubon) focused on conservation of the Kittatinny Ridge and a phenology (as citizen science) project.

## *Section IV*

# *Conclusions from the Ecological Assessment – Part II and Recommendations for the Future*

## *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 Disraeli<sup>1</sup> 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](http://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

---

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

Palmerton Zinc Pile Superfund Site and Lehigh Gap.”<sup>2</sup> 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

---

<sup>2</sup> 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.”<sup>3</sup> 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

---

<sup>3</sup> See [http://www.ser.org/content/ecological\\_restoration\\_primer.asp](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)<sup>4</sup> and Walter, *et al.*<sup>5</sup>.

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

---

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

<sup>5</sup> 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 Gap<sup>6</sup>; 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.*<sup>3</sup> includes a 7<sup>th</sup> “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)<sup>4</sup> and images from old post cards actually provide a glimpse as to what that condition might have been.

---

<sup>6</sup> 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.<sup>7</sup> 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 County<sup>8</sup> 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

---

<sup>7</sup>  
<http://freepages.genealogy.rootsweb.ancestry.com/~oplifam/Second%20Generation.html>

<sup>8</sup>  
[http://freepages.genealogy.rootsweb.ancestry.com/~carbdat/m&h/ch\\_2.htm](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.<sup>9,10</sup>

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”.<sup>11</sup> The EPA defines **ecological revitalization** as “the process of returning land from a contaminated state to one that supports a functioning and sustainable habitat”.<sup>11</sup> 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.”<sup>12</sup>*

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.<sup>10</sup>

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

---

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

<sup>10</sup> 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](http://www.clu-in.org/download/issues/ecotools/Ecological_Revitalization_Turning_Contaminated_Properties_into_Community_Assets.pdf). Accessed January 7, 2011.

---

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

<sup>12</sup> 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](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 Lehigh). 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).<sup>13</sup> 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).<sup>14</sup>*

---

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

<sup>14</sup> 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”.<sup>15</sup>

According to Lessard<sup>16</sup> and Macey<sup>17</sup> 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. Macey<sup>12</sup> 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.<sup>18</sup>

---

<sup>15</sup> 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

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

<sup>17</sup> 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.

---

<sup>18</sup> 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)<sup>19</sup>, 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.*

Macey<sup>12</sup> 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

---

<sup>19</sup> 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.<sup>20</sup>*

Latham also referred us to the technical document on “Desired Conditions for Natural Resources” used by the National Park Service.<sup>21</sup> 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) a **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

---

<sup>20</sup> 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.

<sup>21</sup> 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.<sup>22</sup>

- 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

---

<sup>22</sup> 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 Resources<sup>23</sup>, 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

---

<sup>23</sup> 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.

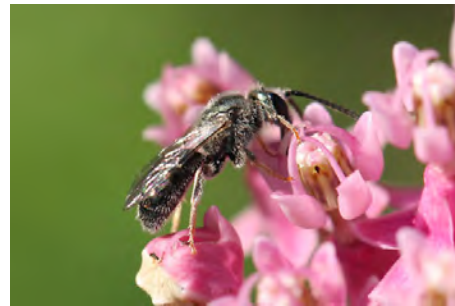
### Research Recommendations

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.

- 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.



*Lithurgus chrysurus*



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

- 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.<sup>24</sup> 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)<sup>21, 25</sup> or whether new vegetation in the restoration areas will eventually out-compete this plant, especially as the heavy metals become less bio-available.

---

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

<sup>25</sup> 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) <sup>26</sup> 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,

---

<sup>26</sup> <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.