Appendix A

List of researchers, consultants, and collaborating partners (and their projects) that contributed to the LGWR Ecological Assessment Part II

Moravian College – Department of Biological Sciences and the Environmental Studies and Science Program

Diane Husic, Ph.D. and undergraduate students:
Sarabeth Brockley
Sandwort studies, succession studies and enhancement plantings, GIS mapping
Yi Li and Gregory Niehoff
Heavy metal impact on plants, especially gray birch
Meredith Wright
Annotated bibliography of the Palmerton Superfund Site and the Lehigh Gap

Frank Kuserk, Ph.D. and undergraduate students:
Andrew F. Mashintonio
Macroinvertebrate Diversity in Metal Contaminated Ponds of the Lehigh Gap Refuge
Armando Villafañe Jr.
Current State of Soil Microflora Post Zinc Smelter Exposure
Vivian Clarke-Ruiz
Evidence for Zinc Tolerance among Bacteria in the Palmerton, PA Area
Nicole Sarson
Identification of Bacteria Found in Metal Contaminated Soils near Palmerton, PA
John Corbin
A Study of the Small Mammals at the Lehigh Gap Wildlife Refuge Using Trapping and Trail Cameras
John Reese
Herbivory of Some Native and Invasive Plant Species at the LGWR

The Conservation Biology, Ecology, and Microbiology classes of Moravian College contributed to the habitat enhancement design and studies, the succession plot studies and the soil microbe analysis work.

Lehigh University - Lehigh Earth Observatory (LEO) and the Department of Earth and Environmental Sciences

Dork Sahagian, Ph.D. and Steve Peters, Ph.D.
Airfall of Metals from the Palmerton, PA Zinc Plant: Distribution and Preservation

Bruce Hargreaves, Ph.D.
Characterization of microclimate at the Lehigh Gap Nature Center

George Yasko
GIS mapping, technical assistance with numerous projects

Johanna Blake, Master of Science student
The Fluxes and Transport Mechanisms of Groundwater and Surface Water Contaminants (Zn, Pb, Cd, As, and Cr) into a Fluvial System: Palmerton, PA; GIS mapping

Jill E. Burrows,
Assessment of Natural Attenuation of Arsenic, Cadmium, Lead and Zinc Using Hydrograph Separation

Guthrie Mitchell, Intern
Light-trap insect trapping and preliminary small mammal trapping studies

Members of the Civil and Environmental Engineering and Geographic Analysis courses and Lehigh graduate students contributed to the installation of the weather stations.

Wilkes University - Institute for Environmental Science and Sustainability and the Department of Biology

Ned Fetcher, Ph.D. Ken Klemow, Ph.D., Michael Steele, Ph.D., Jeff Stratford, George Haleem, and Rachel Curtis
Food Webs and Ecosystem Restoration; assistance with insect traps

West Virginia University - Departments of Biology and Geology and Geography

Jonathan Cummings, Ph.D.
Dorothy J. Vesper, Ph.D.

Ernest Smith
Zinc Tolerance Mechanisms in Poplar

Christian Figueroa and Ernest Smith
Plant-rhizosphere Interactions and Responses to Potentially Toxic Elements

University of Pennsylvania – Department of Biology

Brenda B. Casper, Ph.D.

Sydney I. Glassman – Masters degree student
Jennifer Doherty – Ph.D. student

High School Student Researchers:
Julia Leinhauser, Sherilin Joe, and Khalia Thompson
Arbuscular Mycorrhizal Fungi (AMF), non-mycorrhizal soil microbes, and plants in a pollution gradient

Muhlenberg College

Patricia Brandt
Historical perspectives of studies related to the Palmerton Zinc story; human health impacts

Lehigh Gap Nature Center Staff

Maria Tranguch
Corey Husic
Dan Kunkle
LGNC interns: Corey Husic, Sarabeth Brockley, Kyle Janny, Mike and Jenny Bet, Jared Green, and Remy Schneider
LGNC volunteers (too numerous to mention all)

Members of the Naturalist Club who participated in the Native Bee study and the Monarch Watch program: Sean Bankos, Brandon Everett, Corey Husic, Joren Husic, Clare Kubik, and others

LGNC Naturalists Projects (supported by the LGNC and the Audubon *TogetherGreen* Fellows Program)

Sean Bankos
Herpetofauna of Lehigh Gap Nature Center

Corey Husic
Bird Inventory of the Lehigh Gap: The Impact of Zinc Smelting and Habitat Restoration, 2006 – 2010;
Bioacoustics Survey: Wildlife Vocalizations at Lehigh Gap Nature Center

Clare Kubik
Bees and Arachnids of Lehigh Gap Nature Center (with help from the Naturalists Club and Anita Collins)

Brandon Everett
Habitat Enhancement of Prairie Warbler Trail Early-successional Habitat

Carnegie Museum of Natural History

John E. Rawlins, Ph.D.
Lehigh Gap Nature Center Preliminary Faunal Assessment for Insects: Part II

Fort Indiantown Gap Staff and Researchers

Shannon Henry, Joseph Hovis, David McNaughton, Mark Swartz, and Virginia Tilden

Consultants on Regal Fritillary habitat and re-introduction and controlled burns for grassland habitat management

Aracadis BBL

Jennifer Lansing and staff

Risk assessment

Vegetative cover analysis

Metal analysis in plants, seep, spring and pond water

Succession monitoring design

Finger Lakes Conservation Services

John Dickerson

Revegetating a Superfund Site with Native Grasses

Continental Conservation

Roger Latham

Grassland Enhancement at Lehigh Gap Nature Center; plant communities

Edge of the Woods Native Plant Nursery

Sue Tantsits and Louise Schaefer

Grassland Enhancement at Lehigh Gap Nature Center; native plant consultants

Green Man Enviroscaping

Everett Warren

Installation of Deer Exclosures; Grassland Enhancement Project

Lafayette College

H. David Husic

Bird Surveys, LGNC website

Audubon, PA

Brian Byrnes

Grassland Enhancement at Lehigh Gap Nature Center

U.S. Department of Energy (Pittsburg) - National Technology Energy Laboratory

Hank Edenborn, Ph.D.

Current State of the Soil Microflora at the Palmerton, Pa Superfund Site

Anita Collins, Ph.D.

Coordinator for Northeast Pennsylvania Native Bee Project and bee identifier

U.S. Geological Survey - Patuxent Wildlife Research Center
Sam Droege
Native bee and wasp studies

Environmental Protection Agency
Charlie Root
Superfund Project Manager

PA Department of Environmental Protection
Jim Kunkle
Superfund Project Manager

PA Game Commission
Dave Henry, Forester
Tree Planting Field Trials

PA Department of Environmental Protection
Ken Beard
Tree Planting Field Trials

Frank & West, Inc.
Jim Frank, Environmental Engineer
Tree Planting Field Trials

Abel Boyer and Family
Tree Planting Field Trials

Audubon TogetherGreen Fellows and Innovation Grant Programs
Habitat Enhancement Project, LGNC Naturalist Projects

CBS Operations
Funding of summer interns

Lehigh Valley Audubon Society

Appendix B

Vertebrates of the Lehigh Gap Wildlife Refuge

(as of December 2010)

Mammals

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 cinerecargenteus*)
Black Bear (*Ursus americanus*)
Raccoon (*Procyon lotor*)
Weasel sp. (*Mustela sp.*)
Mink (*Mustela vison*)
River Otter (*Lutra canadensis*)
White-tailed Deer (*Odocoileus virginianus*)

Fish

American Eel (*Anguilla rostrata*)
Pickerel sp. (*Esox sp.*)
Rainbow Trout (*Oncorhynchus mykiss*)
Brown Trout (*Salmo trutta*)
Green Sunfish (*Lepomis cyanellus*)

Reptiles and Amphibians

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 versiclor*)
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*)
Longtail Salamander (*Eurycea longicauda*)
Four-toed Salamander (*Hemidactylium scutatum*)
Northern Redback Salamander (*Plethodon cinereus*)
Northern Red Salamander (*Pseudotriton ruber*)
Red-spotted Newt (*Notophthalmus viridescens*)

Birds

Snow Goose (*Chen caerulescens*)
Canada Goose (*Branta canadensis*)
Wood Duck (*Aix sponsa*)
American Black Duck (*Anas rubripes*)
Mallard (*Anas platyrhynchos*)
Blue-winged Teal (*Anas discors*)
Green-winged Teal (*Anas crecca*)
Ring-necked Duck (*Aythya collaris*)
Bufflehead (*Bucephala albeola*)
Common Goldeneye (*Bucephala clangula*)
Hooded Merganser (*Lophodytes cucullatus*)

Common Merganser (*Mergus merganser*)
Ring-necked Pheasant (*Phasianus colchicus*)
Ruffed Grouse (*Bonasa umbellus*)
Wild Turkey (*Meleagris gallopavo*)
Common Loon (*Gavia immer*)
Pied-billed Grebe (*Podyilymbus podiceps*)
Double-crested Cormorant (*Phalacrocorax auritus*)
Great Blue Heron (*Ardea herodias*)
Great Egret (*Ardea alba*)
Green Heron (*Butorides virescens*)
Black Vulture (*Coragyps atratus*)
Turkey Vulture (*Cathartes aura*)
Osprey (*Pandion haliaetus*)
Bald Eagle (*Haliaeetus leucocephalus*)
Northern Harrier (*Circus cyaneus*)
Sharp-shinned Hawk (*Accipiter striatus*)
Cooper's Hawk (*Accipiter cooperii*)
Northern Goshawk (*Accipiter gentilis*)
Red-shouldered Hawk (*Buteo lineatus*)
Broad-winged Hawk (*Buteo platypterus*)
Swainson's Hawk (*Buteo swainsoni*)
Red-tailed Hawk (*Buteo jamaicensis*)
Rough-legged Hawk (*Buteo lagopus*)
Golden Eagle (*Aquila chrysaetos*)
American Kestrel (*Falco sparverius*)
Merlin (*Falco columbarius*)
Peregrine Falcon (*Falco peregrinus*)
Killdeer (*Charadrius vociferus*)
Spotted Sandpiper (*Actitis macularius*)
Solitary Sandpiper (*Tringa solitaria*)
Wilson's Snipe (*Gallinago delicata*)
American Woodcock (*Scolopax minor*)
Ring-billed Gull (*Larus delawarensis*)
Herring Gull (*Larus argentatus*)
Great Black-backed Gull (*Larus marinus*)
Rock Pigeon (*Columba livia*)
Mourning Dove (*Zenaida macroura*)
Yellow-billed Cuckoo (*Coccyzus americanus*)
Black-billed Cuckoo (*Coccyzus erythropthalmus*)
Great Horned Owl (*Bubo virginianus*)
Common Nighthawk (*Chordeiles minor*)
Whip-poor-will (*Caprimulgus vociferus*)
Chimney Swift (*Chaetura pelagica*)
Ruby-throated Hummingbird (*Archilochus colubris*)
Belted Kingfisher (*Megaceryle alcyon*)
Red-bellied Woodpecker (*Melanerpes carolinus*)

Yellow-bellied Sapsucker (*Sphyrapicus varius*)
Downy Woodpecker (*Picoides pubescens*)
Hairy Woodpecker (*Picoides villosus*)
Northern Flicker (*Colaptes auratus*)
Pileated Woodpecker (*Dryocopus pileatus*)
Olive-sided Flycatcher (*Contopus cooperi*)
Eastern Wood-Pewee (*Contopus virens*)
Willow Flycatcher (*Empidonax traillii*)
Least Flycatcher (*Empidonax minimus*)
Eastern Phoebe (*Sayornis phoebe*)
Great Crested Flycatcher (*Myiarchus crinitus*)
Eastern Kingbird (*Tyrannus tyrannus*)
White-eyed Vireo (*Vireo griseus*)
Blue-headed Vireo (*Vireo solitarius*)
Warbling Vireo (*Vireo gilvus*)
Philadelphia Vireo (*Vireo philadelphicus*)
Red-eyed Vireo (*Vireo olivaceus*)
Blue Jay (*Cyanocitta cristata*)
American Crow (*Corvus brachyrhynchos*)
Fish Crow (*Corvus ossifragus*)
Common Raven (*Corvus corax*)
Purple Martin (*Progne subis*)
Tree Swallow (*Tachycineta bicolor*)
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)
Bank Swallow (*Riparia riparia*)
Cliff Swallow (*Petrochelidon pyrrhonota*)
Barn Swallow (*Hirundo rustica*)
Carolina Chickadee (*Peocile carolinensis*)
Black-capped Chickadee (*Poecile atricapillus*)
Tufted Titmouse (*Baeolophus bicolor*)
Red-breasted Nuthatch (*Sitta canadensis*)
White-breasted Nuthatch (*Sitta carolinensis*)
Brown Creeper (*Certhia americana*)
Carolina Wren (*Thryothorus ludovicianus*)
House Wren (*Troglodytes aedon*)
Winter Wren (*Troglodytes troglodytes*)
Golden-crowned Kinglet (*Regulus satrapa*)
Ruby-crowned Kinglet (*Regulus calendula*)
Blue-gray Gnatcatcher (*Polioptila caerulea*)
Eastern Bluebird (*Sialia sialis*)
Veery (*Catharus fuscescens*)
Swainson's Thrush (*Catharus ustulatus*)
Hermit Thrush (*Catharus guttatus*)
Wood Thrush (*Hylocichla mustelina*)
American Robin (*Turdus migratorius*)
Gray Catbird (*Dumetella carolinensis*)

Northern Mockingbird (*Mimus polyglottos*)
Brown Thrasher (*Toxostoma rufum*)
European Starling (*Sturnus vulgaris*)
Cedar Waxwing (*Bombycilla cedrorum*)
Blue-winged Warbler (*Vermivora pinus*)
Tennessee Warbler (*Vermivora peregrina*)
Orange-crowned Warbler (*Vermivora celata*)
Nashville Warbler (*Vermivora ruficapilla*)
Northern Parula (*Parula americana*)
Yellow Warbler (*Dendroica petechia*)
Chestnut-sided Warbler (*Dendroica pensylvanica*)
Magnolia Warbler (*Dendroica magnolia*)
Cape May Warbler (*Dendroica tigrina*)
Black-throated Blue Warbler (*Dendroica caerulescens*)
Yellow-rumped Warbler (*Dendroica coronata*)
Black-throated Green Warbler (*Dendroica virens*)
Blackburnian Warbler (*Dendroica fusca*)
Pine Warbler (*Dendroica pinus*)
Prairie Warbler (*Dendroica discolor*)
Palm Warbler (*Dendroica palmarum*)
Bay-breasted Warbler (*Dendroica castanea*)
Blackpoll Warbler (*Dendroica striata*)
Black-and-white Warbler (*Mniotilta varia*)
American Redstart (*Setophaga ruticilla*)
Worm-eating Warbler (*Helmitheros vermivorum*)
Ovenbird (*Seiurus aurocapilla*)
Northern Waterthrush (*Seiurus noveboracensis*)
Louisiana Waterthrush (*Seiurus motacilla*)
Mourning Warbler (*Oporornis philadelphia*)
Common Yellowthroat (*Geothlypis trichas*)
Wilson's Warbler (*Wilsonia pusilla*)
Canada Warbler (*Wilsonia candensis*)
Scarlet Tanager (*Piranga olivacea*)
Eastern Towhee (*Pipilo erythrophthalmus*)
American Tree Sparrow (*Spizella arborea*)
Chipping Sparrow (*Spizella passerina*)
Field Sparrow (*Spizella pusilla*)
Vesper Sparrow (*Pooecetes gramineus*)
Savannah Sparrow (*Passerculus sandwichensis*)
Grasshopper Sparrow (*Ammodramus savannarum*)
Fox Sparrow (*Passerella iliaca*)
Song Sparrow (*Melospiza melodia*)
Swamp Sparrow (*Melospiza georgiana*)
White-throated Sparrow (*Zonotrichia albicollis*)
White-crowned Sparrow (*Zonotrichia leucophrys*)
Dark-eyed Junco (*Junco hyemalis*)

Snow Bunting (*Plectrophenax nivalis*)
Northern Cardinal (*Cardinalis cardinalis*)
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)
Blue Grosbeak (*Passerina caerulea*)
Indigo Bunting (*Passerina cyanea*)
Red-winged Blackbird (*Agelaius phoeniceus*)
Eastern Meadowlark (*Sturnella magna*)
Common Grackle (*Quiscalus quiscula*)
Brown-headed Cowbird (*Molothrus ater*)
Orchard Oriole (*Icterus spurius*)
Baltimore Oriole (*Icterus galbula*)
Purple Finch (*Carpodacus purpureus*)
House Finch (*Carpodacus mexicanus*)
White-winged Crossbill (*Loxia leucoptera*)
Common Redpoll (*Carduelis flammea*)
Pine Siskin (*Carduelis pinus*)
American Goldfinch (*Carduelis tristis*)
House Sparrow (*Passer domesticus*)

Appendix C-2

Tips on How to Use Bee Bowls to Collect Bees

Sam Droege

The Bowl

Bee Bowls are small colored plastic bowls or cups that are filled with soapy water. Bees are attracted to these colors, fly into the water, and drown. Bee bowling has evolved toward the use of smaller bowl sizes than the original 12 oz. salad bowl as it was realized that size of bowl was not necessarily correlated with capture rates (see http://online.sfsu.edu/~beeplot/ for several reports that document those results).

Currently, we are no longer using bowls at all but items that are listed in plastic manufacturer's catalogs as soufflé cups. We are not aware of other manufacturer's lines, but Solo has a large selection of soufflé cups that we have experimented with. These cups usually come in their native translucent plastic color, which is not at all attractive to bees. However the 3.25 oz. cup, which is steep sided and stable on the ground, does come in white (model number: p325w-0001) and appears to provide a better color base than the translucent ones.

The 0.75 oz. and perhaps the 2 oz. cups are nice sizes to carry around and minimize water use (they are particularly useful to have when you travel), but appear to lose too much water in hot, low humidity areas. The 1 oz. cups are more steep-sided and narrow (and therefore more unstable). However, this model may be worth investigating for use in desert areas. Surprisingly, loss or upsetting by the wind is almost never an issue with bee bowls.

These cups usually need to be ordered or picked up from a local Solo distributor and are almost always available only in case lots (usually that means about 2500 cups). Solo distributors can be located by calling 1-800-FOR-CUPS. The solo product line catalog is online and can be viewed at: www.solocups.com. The price for a case is usually in the $50 to $80 buck line. However, periodically I have found these cups in small lots on commercial food service web sites. Do a Google search on the model number and see what you can find. If you are in a real bind email me (sdroege@usgs.gov) and we might be able to help you out.

Painting Bowls

Originally, when bowls rather than soufflé cups were being used, colored plastic bowls from party stores or other sources were used to capture bees. The usual colors were yellow, white, light blue, and dark blue. Those worked well, but fluorescent yellow and fluorescent blue were found to be much more effective in the East. However note that Laurence Packer has found that cactus bees, especially

Macrotera, seem to be attracted to dark blue and even red colored bowls. He didn't compare these with fluorescent colors, but both those colors collected more *M. texana* than did either white or yellow.

Unfortunately it was found that commercially available fluorescent spray and brush paints varied in their characteristics and availability by brand and location. In 2003 we experimented with creating a standardized fluorescent yellow and blue paint from scratch and have done so with the help of the West Coast Risk Reactor Company (800-803-5281) (http://www.riskreactor.com/) who can be contacted both for price and ordering information as well as a complete spec sheets that list this paint's components . In 2004 we experimented with some different formulations and found a fluorescent combination from the East Coast Guerra Paint and Pigment that works much better than the system we had earlier tried. The liquid pigments mix much more readily than the dry pigments do and the base paint they supply sticks well to plastic. When ordering from Guerra specify:

Silica Flat
Yellow Fluorescent
Blue Fluorescent

212-529-0628

Jody was the person we have worked with.

You can order online at:
http://www.guerrapaint.com/tandc.html

To get to the fluorescent pigments click on "Search By Group" and run the scroll bar down to the bottom and click on "Fluorescent." Choose "Fluorescent Blue" or Fluorescent Yellow" from the list of the size and quantity you desire.

To get to the silica flat click on "Search by Type" and choose "Binder" from the list choose the size and amount of "Silica Flat" you need.

The ratio is 16 oz. of dye to 1 gallon of Silica Flat Paint. You can mix it with a stick without difficulty.

For future reference their Fluorescent (water-dispersed pigments) formula is:

Water	47.5%	
Methocel – KMS – Thickener – Methyl Cellulose	0.45%	
Defoamer – Drew -647	0.80%	
Tamol 731 – Dispersant (soap)	1.25%	
Fluorescent Pigment		50.0%

The formula for the Silica Flat Acrylic Latex Paint is:

Acrylic-Latex
Calcium Carbonate
Kaolin – Clay
Titanium Dioxide

No percentages were given and these are only listed as the major components, there are likely to be surfactants and other things in here as well. The carrier of the dye is not as important as the dye itself.

Most paint does not stick well to plastic. Many commercial can spray paints have added compounds that do help with adhesion, but as with most commercial paints those formulations are proprietary. Additionally, if many bowls are being painted, a can of spray paint becomes both expensive and wasteful. We also found using liquid paint in compressed air spray guns to not be worth the cost and trouble. The paint inevitably clogged the sprayer (even when thinned) and it was difficult to coat all the sides and bottom uniformly. However, if you figure out a system please let us know. Oil-based primers will work as will likely primers that have a shellac base or are formulated for glossy surfaces; most big paint stores have such things. Most commercial spray can paints will stick to plastic bowls. We found that white primer looks the best as a base for fluorescent yellow and a gray primer (any good paint shop will tint your primer for free) works best for the fluorescent blue. However, many of these primers often will bead up to some extent (The primer from Guerra does not). Sanding the bowls also allows paint to stick, but takes too much time.

Using a brush to put on primer worked adequately for bowls, but not so well for cups. Two other techniques seemed to be faster and more complete. One technique was to don latex gloves and dip a bit of rag in the paint and rub it all over the cup or bowl. The other technique was to use a very small foam roller of the type often used in edging to apply the paint. This, in particular, worked well for applying the final coat of fluorescent paint. However, neither of these techniques seemed to consistently produce a particularly pretty paint job, usually there would be places remaining where the paint would not stick. So, if anyone comes up with a better means of painting these bowls we would love to hear about it. In 2003 we completed a series of small experiments that indicated that the amount of surface area painted did influence the number of bees captured. When bowls were placed next to each other the bowl with the more paint (about 50% more) caught more bees. This may effect may disappear if bowls were spaced apart.

If using a commercial spray paint, the Krylon brands seems to be composed of the same colors as those from the paint specialty shops, but this brand can be hard to find in many areas (particularly the fluorescent blue).

In 2004 a student placed a set of 3.25 oz. plastic bowls painted fluorescent yellow and blue with pigments from 2 separate suppliers out in the sun (empty) for 6 months starting in early September. The blues became slightly faded and the yellows quite a bit more so, but both were still pigmented. She mentioned that she only noticed fading after 3.5 months of being out in the sun and then only in comparison with bowls that had been kept indoors. Consequently, it looks like the pigments from Guerra and Risk Reactor are quite long-lived and will essentially outlast the life of the plastic bowl - which became quite brittle towards the end. It would be interesting to try this same experiment in some mid-summer southern hemisphere desert and see what the life expectancy is under those conditions.

How to Set a Bowl Trap

A bowl trap is set when it is filled with soapy water and left outside. The soap decreases the surface tension so that even small insects sink if they land on the surface. Most insects stop moving within 60 seconds of hitting the water. However, we have found that many of these insects will wake back up if not either placed in alcohol for several hours or put in the freezer prior to pinning. We have noted that unpinned insects that do wake back up never regain normal behavior and usually simply stand or move very slowly following being in the trap.

Experiments have found that as long as there is water in the bowl or cup it will catch bees at about the same rate as one that is full to the top. However, in hot and arid climates bowls can dry out if not completely filled or if they are too shallow. Currently we advocate that people use either Blue Dawn Dishwashing soap or laboratory detergent. Lemon-scented detergents and ammonia appear to have decreased catch compared to these soaps. Laundry soaps have been tried and do work, but contain so many other fragrance chemicals that we fear that changes in formulation could easily change the catch. In 2005 we will be running experiments with Sodium Laurel Sulfate, sugar, and scents to see we can come up with a standardized soap and determine if other attractants might increase the catch. We have found it easiest to add a big squirt of soap directly to a gallon jug of water rather than adding soap to each bowl.

When using bowls to collect rather than monitor, it is often useful to leave them out for longer periods of time. Laurence Packer has found that propylene glycol will remain in the larger bowls for about 3 weeks even in early summer in the southern Atacama Desert. A bit of formalin in the bowls will decrease the attraction of vertebrates. Under those long and windy conditions, digging the bowl into the substrate is necessary. Tenebrionids, scorpions and the occasional lizard may also be collected in some circumstances.

Matthew Somers ran some experiments in Ontario that indicated that there wasn’t a significant difference in the number of bees captured between yellow bowls filled with soapy water versus those filled with propylene glycol. Interestingly, he found that about 33% of the bees that landed in either fluid would escape the bowl and that some of these differences apparently varied with species. He also noted that a high proportion of insects were attracted to the bowls but either only flew low over them or simply landed on the rim. It would be interesting to test clear barriers placed in the traps to knock down a greater proportion of catch.   This was a small pilot study, worth repeating and expanding upon.

Several people have tried using urine instead of water in the bowls (bees in tropical areas are often attracted to urine soaked soils) but no great increase in catch was noted of the few who tried, but this is worth more investigating.

Sunny days are best for setting out bee bowls. The effects of temperature are unclear but catch appears to be reduced in the spring if temperatures are in the 50's F or below. However, in the fall temperature seems to have less impact. Cloudy days catch few bees, and rainy ones never catch bees.

Where to Set a Bowl Trap

The best places to put bee bowls are exposed open settings....places where bees are likely to see them. This includes almost all habitats. In North America the exceptions are woodlands once the spring blooming period for forbs and woody vegetation is over, and under any dense vegetation (e.g., thick cool season grasses, leafy shrubs). Open warm season grasslands often have good capture rates of bees if the grass over story is not too thick. The general rule of thumb is that if you can easily see the bowl then bees can too. Flowers need not be apparent in an area in order for catches to be quite high. However, the presence of a superabundant nectar and pollen source (e.g., creosote bush or mesquite) often appears to lead to low bowl capture rates.

Bowls seem to work around the world with examples of them working well in Fiji, Thailand, South Africa, Central America, and South America. Bycatch in bee bowls can be very interesting with loads of parasitic hymenoptera, specids, vespids, skippers, thrips, and other things that often come to flowers.

In tropical Central and South America Dave Roubik (Panama), Steve Javorek (Belize), and Gordon Frankie (Costa Rica) have all noticed that soapy water bowls capture almost no bees in closed canopy or canopy top situations (however, more extensive tests are warranted here), but are successful in open habitats. Roubik also has had good success with capturing stingless bees using a honey solution (or sucrose when honey is not available) either in bowls or sprayed on vegetation.

Laurence Packer writes about strategies for collecting bees in bowls: "When attempting to collect Xeromelissinae, some of which are oligolectic, I have often put pans out by suitable looking flowers en route to a different collecting spot. The success rate has been remarkably high and I have found males of species only collected by net as females, and females of species only collected by net as males using this method.

By placing pans adjacent to the flowers visited by oligolectic species. I have managed to collect samples directly into buffered formalin and absolute alcohol for histology and DNA respectively - though capture rates were not high, in a couple of hours a couple of pans of each collected enough for my needs.”

In general small bees are sampled well in bowls, but larger bees often need to be netted.

Most researchers put bowls out in strings rather than as single bowls. Capture rate per unit of field time is much higher this way. Once a location has been chosen in which to place bowls it takes relatively little additional time to place many bowls as compared to just one, particularly when compared to the cost of traveling to a new place. An internal study available from Sam Droege (301 497 5840, sam_droege@usgs.gov) indicated that the variances for characterizing the species richness of a single site may level out after 15- 30 bowls at one site. Bowls placed right next to each other have been shown to have reduced per/bowl capture rates. The specific distances at which capture rates among bowls equalizes or becomes insignificant for bees is unclear, it would appear, however, that per bowl capture rate may stop declining after even distances as short as 5m. In Brazil additional species were captured when bowls were elevated off the ground, but in the Eastern United States no additional species were captured and capture rates were much lower than bowls placed on the ground. In the East, when large black circles were added to the bottom of cups catch was decreased, while adding small Andrena-sized markings to a bowl did not change capture rates.

A procedure has been developed for monitoring bees on plots and is available at Gretchen LeBuhn’s bee monitoring web site (http://online.sfsu.edu/~beeplot/). A scheme for replicable monitoring or inventory of bees over larger landscapes is being developed by Sam Droege (sam_droege@usgs.gov). That design will likely include the superimposing of a grid over the landscape with numerous individual transects of 12-20 bowls taken within each grid in appropriate habitats and used as replicates. Because a completely random or systematic sampling scheme is impossible in most public/private landscapes, an effort will be made to GPS all points and collect habitat co-variates to permit counts to be adjusted over time.

How to Collect the Bees Once Trapped

At each bowl it is usually best to pick out all moths, butterflies, and skippers as well as slugs, and very large bodied non-hymenoptera (e.g. grasshoppers and crickets). These groups tend to contaminate the other specimens when placed in alcohol. The next step is to dump the bees either into an aquarium net, sieve, or tea strainer. The key matter when choosing a particular type of bee strainer is that their mesh must be fine enough to catch the smallest of bees some of which may only be 2-4mm. If using an aquarium net, look specifically for brine shrimp rather than regular nets. In general most kitchen sieves are too coarse while most tea strainers have nice fine mesh. Brine shrimp nets are our favorites.

Usually researchers pool all the bowls from one transect or plot rather than keeping individual trap data, as handling time increases greatly when collecting from individual bowls. Many researchers also wash the soap from their catch in the field using a squirt bottle; however, we have found that not to be necessary. Most researchers then store their catch in 70% alcohol in whirlpaks. We usually pick out the mass of insects in the net or strainer with our fingers and dump it into an individual whirlpak. However, Frank Parker uses a larger sized whirlpak along with a small tea strainer and then gives the strainer a sharp rap when in the bag to dislodge all the insects at once.

Isopropyl, ethyl, or denatured alcohols are all appropriate for storing insects, but isopropyl should never be mixed with the other alcohols. These alcohols can be found in drug or hardware stores. You can go to the pharmacy and almost always find small pint bottles of ethyl alcohol, ethanol, or denatured alcohol (they aren't very consistent in what they call them), if not, they will readily order it for you. At the hardware store they have gallon and pint jars of denatured alcohol (these are 100% alcohol and almost always contain a mix of 50% ethanol and 50% methanol). The drug store alcohol seems to be easier to work with as it is often made with a smaller amount of methanol and smells better.

Often the alcohol needs to be diluted to achieve the right percentage (70%). All hardware store alcohol should be considered to be 100% alcohol. Drug store alcohol can be close to 100% but also can be something less so you will have to read the bottle's label to check. To add confusion to the matter drugstores often label the percent alcohol in terms of "proof." Proof is a simple doubling of the percentage. Therefore 100 proof is 50% alcohol and 190 proof is 95% alcohol. To dilute from 100% alcohol to 70%, choose a convenient sized container, such as a pint bottle, then fill it ~70% full with alcohol and the rest with tap water. This measurement doesn't need to be exact.

Working with Miriam Richards from Brock University has found that specimens stored and processed as above retain high quality DNA for at least several years. Further work in 2005 is meant to clarify this.

The process for washing bees after they have been in alcohol is available at: http://online.sfsu.edu/~beeplot/. The difference between a good bee collector/researcher and a poor one can be told by how well they wash their bees, so don't skip this step!

Bob Minckley has found that when he does collections from individual bowls it is useful to use clear plastic fishing lure boxes. The compartments can be numbered and individual bees picked out of bowls by hand and placed in the appropriate compartment. Afterwards, he freezes the entire container for at least 10 minutes to keep anything from re-awakening and then pins them straight from the box. Sometimes these specimens are more matted than ones that have been properly washed, but most of the time they area readily identifiable to species.

Another alternative to whirpaks is to dump the catch into small numbered squares of cloth which are then rolled up and rubber banded together. Once back from the field these are collected, put into Ziploc bags and frozen until ready for pinning.

In all cases each bag, fishing box, or cloth should have a tag listing the sample location and date written on paper with pencil. Do not trust any kind of writing to stay on the outsides of a whirlpak bag as they inevitably get wet with alcohol or water and run.

A Few Little Efficiency Tips

When setting up for a day of putting out bowls we have found that it is helpful to make up your batches of bowls the day before and have them in a tray or box on the passenger seat. Wire flags (very useful for refinding your transects when driving at 60 mph) can be set in the passenger foot well. If working in a 4-door car we have found it fastest to keep the jug of soapy water on the back seat or on the floor of the back seat behind the driver. When the driver gets out they can grab a set of bowls and a flag in their right hand, open the door with their left hand, leap out of the car, pivot and grab the jug through the back window and then sprint off to put out bowls.

We have learned the hard way that getting into and out of the car many times a day to put out bee bowls can be hard on the human body. In particular it is hard on the left leg as it levers you into and out of the car and may lead to some slow healing muscle strains. The best way to get in is to sit down on the seat first and then swing both legs over. Getting out is the reverse operation swinging both legs out and then standing up.

Bee Monitoring Discussion List and Announcements

If you are interested in bee monitoring or identification issues you might want to sign up for the 2beeornot2bee listserv. Discussions and announcements are relatively few, but can alert you to interesting developments.

Go to http://rana.er.usgs.gov/read/all_forums/ to sign in.

Archives can be read at:

http://rana.er.usgs.gov/read/all_forums/

Appendix C-3

Preliminary List of Bee Species Identified in the 2007 LGWR-USGS Survey

Andrena carlini
Andrena cressonii
Anthidium oblongata
Augochlorella aurata
Bobmus impaciens
Caliopsis andreniformis
Ceratina calcarata
Colletes inequalis
Halictus confusus
Halictus ligatus
Halictus rubicundus
Lasioglossum abanci
Lasioglossum admirandum
Lasioglossum albiventris
Lasioglossum asteris
Lasioglossum cressonii
Lasioglossum foxli
Lasioglossum heteregnathum
Lasioglossum illinoense
Lasioglossum imitatum
Lasioglossum pectorale
Lasioglossum pilosum
Lasioglossum rohweri
Lasioglossum tegulare
Lithurgus chrysurus
Megachile texana
Nomada form K
Nomada pygmaea
Osmia albiventris
Osmia lignara
Osmia pumila

In addition to the identified species, two unidentified *Lasioglossum* species and one unidentified *Osmia* species were captured.

Appendix C-4

Species list for Lepidopterans and Odonatans at the LGWR

(as of December 2010)

DAMSELFLIES

Ebony Jewelwing (*Calopteryx maculata*)
Elegant Spreadwing (*Lestes inaequalis*)
Slender Spreadwing (*Lestes rectangularis*)
Swamp Spreadwing (*Lestes vigilax*)
Eastern Red Damsel (*Amphiagrion saucium*)
Variable Dancer (*Argia fumipennis*)
Powdered Dancer (*Argia moesta*)
Azure Bluet (*Enallagma aspersum*)
Familiar Bluet (*Enallagma civile*)
Orange Bluet (*Enallagma signatum*)
Fragile Forktail (*Ischnura posita*)
Eastern Forktail (*Ischnura verticalis*)

DRAGONFLIES

Common Green Darner (*Anax junius*)
Black-shouldered Spinyleg (*Dromogomphus spinosus*)
Lancet Clubtail (*Gomphus exilis*)
Prince Baskettail (*Epitheca princeps*)
Calico Pennant (*Celithemis elisa*)
Eastern Pondhawk (*Erythemis simplicicollis*)
Dot-tailed Whiteface (*Leucorrhinia intacta*)
Spangled Skimmer (*Libellula cyanea*)
Slaty Skimmer (*Libellula incesta*)
Widow Skimmer (*Libellula luctuosa*)
Twelve-spotted Skimmer (*Libellula puchella*)
Blue Dasher (*Pachydiplax longipennis*)
Common Whitetail (*Plathemis lydia*)
Ruby Meadowhawk (*Sympetrum rubicundulum*) (tentative identification)
Autumn Meadowhawk (*Sympetrum vicinum*)
Black Saddlebags (*Tramea abdominalis*)

BUTTERFLIES

Black Swallowtail (*Papilio polyxenes*)
Eastern Tiger Swallowtail (*Papilio glaucus*)
Spicebush Swallowtail (*Papilio troilus*)
Cabbage White (*Pieris rapae*)
Clouded Sulphur (*Colias philodice*)
Orange Sulphur (*Colias eurytheme*)
Banded Hairstreak (*Satyrium calanus*)
Gray Hairstreak (*Strymon melinus*)
Eastern Tailed-Blue (*Everes comyntas*)
Spring Azure (*Celastrina ladon*)
Summer Azure (*Celastrina neglecta*)
Great Spangled Fritillary (*Speyeria cybele*)
Aphrodite Fritillary (*Speyeria aphrodite*)
Pearl Crescent (*Phyciodes tharos*)
Question Mark (*Polygonia interrogationis*)
Eastern Comma (*Polygonia comma*)
Mourning Cloak (*Nymphalis antiopa*)
Milbert's Tortoiseshell (*Nymphalis milberti*)
American Lady (*Vanessa virginiensis*)
Red Admiral (*Vanessa atalanta*)
Common Buckeye (*Junonia coenia*)
Red-spotted Admiral (*Limenitis arthemis*)
Viceroy (*Limenitis archippus*)
Little Wood-Satyr (*Megisto cymela*)
Common Wood-Nymph (*Cercyonia pegala*)
Northern Pearly-eye (*Enodia anthedon*)
Monarch (*Danaus plexippus*)
Silver-spotted Skipper (*Epargyreus clarus*)
Dreamy Duskywing (*Erynnis icelus*)
Juvenal's Duskywing (*Erynnis juvenalis*)
Wild Indigo Duskywing (*Erynnis baptisiae*)
Swarthy Skipper (*Nastra lherminier*)
Least Skipper (*Ancyloxpha numitor*)
Peck's Skipper (*Polites peckius*)
Tawny-edged Skipper (*Polites themistocles*)
Northern Broken-Dash (*Wallengrenis egeremet*)
Little Glassywing (*Pompeius verna*)
Delaware Skipper (*Anatrytone logan*)

Hobomok Skipper (*Poanes hobomok*)
Zabulon Skipper (*Poanes zabulon*)
Dun Skipper (*Euphyes vestris*)
Common Roadside-Skipper (*Amblyscirtes vialis*)

Appendix C-5

Compilation of Insect Species at the LGWR

(as of December 2010)

Genus	Species		Family	Order
				Blattodea
			Aderidae	Coleoptera
Agrilus	*anxius*		Agrilus	Coleoptera
Agrilus	*bilineatus*		Agrilus	Coleoptera
Chrysobothris	*femorata*		Agrilus	Coleoptera
Chrysobothris	*rugosiceps*		Agrilus	Coleoptera
			Anobiidae	Coleoptera
			Anthicidae	Coleoptera
			Anthicidae	Coleoptera
Ischalia	*costata*		Anthicidae	Coleoptera
Euparius			Anthribidae	Coleoptera
			Bostrichidae	Coleoptera
			Cantharidae	Coleoptera
			Cantharidae	Coleoptera
Chauliognathus			Cantharidae	Coleoptera
Podabrus			Cantharidae	Coleoptera
Acupalpus	*carus*		Carabidae	Coleoptera
Acupalpus	*indistinctus*		Carabidae	Coleoptera
Acupalpus	*pauperculus*		Carabidae	Coleoptera
Acupalpus	*pumilus*		Carabidae	Coleoptera
Acupalpus	*rectangulus*		Carabidae	Coleoptera
Agonum	*aeruginosum*		Carabidae	Coleoptera
Agonum	*decorum*		Carabidae	Coleoptera
Agonum	*extensicolle*		Carabidae	Coleoptera
Agonum	*galvestonicum*		Carabidae	Coleoptera
Agonum	*harrisii*		Carabidae	Coleoptera
Agonum	*lutulentum*		Carabidae	Coleoptera
Agonum	*melanarium*		Carabidae	Coleoptera
Agonum	*moerens*		Carabidae	Coleoptera
Agonum	*tenue*		Carabidae	Coleoptera
Amara	*cupreolata*		Carabidae	Coleoptera
Amara	*lunicollis*		Carabidae	Coleoptera
Amara	*patruelis*		Carabidae	Coleoptera
Amphasia	*interstitalis*		Carabidae	Coleoptera
Amphasia	*sericea*		Carabidae	Coleoptera
Anisodactylus	*harrisii*		Carabidae	Coleoptera
Anisodactylus	*melanopus*		Carabidae	Coleoptera
Anisodactylus	*nigerrimus*		Carabidae	Coleoptera
Anisodactylus	*rusticus*		Carabidae	Coleoptera
Anisodactylus	*verticalis*		Carabidae	Coleoptera
Apenes	*lucidulus*		Carabidae	Coleoptera

Bembidion	*affine*		Carabidae	Coleoptera
Bembidion	*impotens*		Carabidae	Coleoptera
Bembidion	*versicolor*		Carabidae	Coleoptera
Bembidion	*patruele*		Carabidae	Coleoptera
Bembidion	*rapidum*		Carabidae	Coleoptera
Bradycellus	*badipennis*		Carabidae	Coleoptera
Bradycellus	*nigriceps*		Carabidae	Coleoptera
Bradycellus	*nigrinus*		Carabidae	Coleoptera
Bradycellus	*rupestris*		Carabidae	Coleoptera
Bradycellus	*semipubescens*		Carabidae	Coleoptera
Bradycellus	*tantillus*		Carabidae	Coleoptera
Carabus	*vinctus*		Carabidae	Coleoptera
Chlaenius	*aestivus*		Carabidae	Coleoptera
Chlaenius	*emarginatus*		Carabidae	Coleoptera
Chlaenius	*pennsylvanicus*		Carabidae	Coleoptera
Cicindela	*punctulata*		Carabidae	Coleoptera
Cicindela	*sexguttata*		Carabidae	Coleoptera
Clinidium	*baldufi*		Carabidae	Coleoptera
Clivina	*acuducta*		Carabidae	Coleoptera
Clivina	*americana*		Carabidae	Coleoptera
Clivina	*bipustulata*		Carabidae	Coleoptera
Clivina	*dentipes*		Carabidae	Coleoptera
Clivina	*impressefrons*		Carabidae	Coleoptera
Colliuris	*pensylvanica*		Carabidae	Coleoptera
Cymindis	*limbatus*		Carabidae	Coleoptera
Cymindis	*pilosus*		Carabidae	Coleoptera
Cymindis	*platicollis*		Carabidae	Coleoptera
Dicaelus	*politus*		Carabidae	Coleoptera
Dromius	*piceus*		Carabidae	Coleoptera
Dyschirius	*globulosus*		Carabidae	Coleoptera
Elaphropus	*tripunctatus*		Carabidae	Coleoptera
Elaphropus	*vernicatus*		Carabidae	Coleoptera
Elaphropus	*vivax*		Carabidae	Coleoptera
Elaphropus	*xanthopus*		Carabidae	Coleoptera
Harpalus	*erythropus*		Carabidae	Coleoptera
Harpalus	*herbivagus*		Carabidae	Coleoptera
Harpalus	*pensylvanicus*		Carabidae	Coleoptera
Harpalus	*rubripes*		Carabidae	Coleoptera
Lebia	*fuscata*		Carabidae	Coleoptera
Lebia	*grandis*		Carabidae	Coleoptera
Lebia	*solea*		Carabidae	Coleoptera
Lebia	*viridis*		Carabidae	Coleoptera
Leptotrachelus	*dorsalis*		Carabidae	Coleoptera
Myas	*cyanescens*		Carabidae	Coleoptera
Notiobia	*terminata*		Carabidae	Coleoptera
Olisthopus	*parmatus*		Carabidae	Coleoptera
Oodes	*amaroides*		Carabidae	Coleoptera
Ophonus	*puncticeps*		Carabidae	Coleoptera
Paratachys	*oblitus*		Carabidae	Coleoptera
Paratachys	*proximus*		Carabidae	Coleoptera

Paratachys	*sagax*		Carabidae	Coleoptera
Paratachys	*scitulus*		Carabidae	Coleoptera
Perigona	*nigriceps*		Carabidae	Coleoptera
Platynus	*parmarginatus*		Carabidae	Coleoptera
Platynus	*tenuicolis*		Carabidae	Coleoptera
Plochionus	*timidus*		Carabidae	Coleoptera
Poecilus	*lucublandus*		Carabidae	Coleoptera
Pterostichus	*corvinus*		Carabidae	Coleoptera
Pterostichus	*luctuosus*		Carabidae	Coleoptera
Pterostichus	*mutus*		Carabidae	Coleoptera
Pterostichus	*tristis*		Carabidae	Coleoptera
Scarites	*subterraneus*		Carabidae	Coleoptera
Selenophorus	*opalinus*		Carabidae	Coleoptera
Sphaeroderus	*stenostomus*		Carabidae	Coleoptera
Stenolophus	*comma*		Carabidae	Coleoptera
Stenolophus	*conjunctus*		Carabidae	Coleoptera
Stenolophus	*fuligiinosus*		Carabidae	Coleoptera
Stenolophus	*lecontei*		Carabidae	Coleoptera
Stenolophus	*ochropezus*		Carabidae	Coleoptera
Stenolophus	*plebejus*		Carabidae	Coleoptera
Syntomus	*americanus*		Carabidae	Coleoptera
Tetraleucus	*picticornis*		Carabidae	Coleoptera
Trichotichnus	*autumnalis*		Carabidae	Coleoptera
Trichotichnus	*dichrous*		Carabidae	Coleoptera
Cephaloon			Cephaloidae	Coleoptera
Analeptura	*lineola*		Cerambycidae	Coleoptera
Anelaphus	*parallelus*		Cerambycidae	Coleoptera
Bellamira	*scalaris*		Cerambycidae	Coleoptera
Brachyleptura	*circumdata*		Cerambycidae	Coleoptera
Clytus	*ruricola*		Cerambycidae	Coleoptera
Eburia	*quadrigeminata*		Cerambycidae	Coleoptera
Elaphidion	*mucronatum*		Cerambycidae	Coleoptera
Guarotes	*cyanipennis*		Cerambycidae	Coleoptera
Leptorhabdium	*pictum*		Cerambycidae	Coleoptera
Metacmaeops	*vittata*		Cerambycidae	Coleoptera
Neoclytus	*acuminatus*		Cerambycidae	Coleoptera
Oberea	*gracilis*		Cerambycidae	Coleoptera
Oberea	*praelonga*		Cerambycidae	Coleoptera
Oberea	*ruficollis*		Cerambycidae	Coleoptera
Phymatodes	*amoenus*		Cerambycidae	Coleoptera
Prionus	*laticollis*		Cerambycidae	Coleoptera
Saperda	*candida*		Cerambycidae	Coleoptera
Strangalia	*famelica*		Cerambycidae	Coleoptera
Strangalia	*luteicornis*		Cerambycidae	Coleoptera
Trachysida	*mutabilis*		Cerambycidae	Coleoptera
Typocerus	*velutinus*		Cerambycidae	Coleoptera
Xylotrechus	*colonus*		Cerambycidae	Coleoptera
Chalepus	*bicolor*		Chrysomelidae	Coleoptera
			Chrysomelidae	Coleoptera
Hispinae			Chrysomelidae	Coleoptera

			Chrysomelidae	Coleoptera
Chariessa	*pilosa*		Cleridae	Coleoptera
			Cleridae	Coleoptera
Enoclerus	*nigripes*		Cleridae	Coleoptera
Enoclerus	*rosmarus*		Cleridae	Coleoptera
Phyllobaenus	*humeralis*		Cleridae	Coleoptera
Anatus	*labiculata*		Coccinellidae	Coleoptera
Coccinella	*septempunctata*		Coccinellidae	Coleoptera
			Coccinellidae	Coleoptera
			Coccinellidae	Coleoptera
			Coccinellidae	Coleoptera
Cycloneda	*munda*		Coccinellidae	Coleoptera
Harmonia	*axyridis*		Coccinellidae	Coleoptera
			Colydiidae	Coleoptera
			Cryptophagidae	Coleoptera
Tenomerga			Cupedidae	Coleoptera
			Curculionidae	Coleoptera
			Curculionidae	Coleoptera
			Curculionidae	Coleoptera
			Curculionidae	Coleoptera
			Curculionidae	Coleoptera
			Curculionidae	Coleoptera
			Curculionidae	Coleoptera
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			Curculionidae	Coleoptera
			Curculionidae	Coleoptera
			Curculionidae	Coleoptera
			Curculionidae	Coleoptera
			Curculionidae	Coleoptera
Dryocoetes	*affaber*		Curculionidae	Coleoptera
Dryocoetes	*autographus*		Curculionidae	Coleoptera
Gnathotrichus	*materiatius*		Curculionidae	Coleoptera
Monarthrum	*mali*		Curculionidae	Coleoptera
Pityophtorus			Curculionidae	Coleoptera
Xyleborus	*californicus*		Curculionidae	Coleoptera
Xyleborus	*ferrugineus*		Curculionidae	Coleoptera
Xyleborus	*xylographus*		Curculionidae	Coleoptera
Helichus			Dryopidae	Coleoptera
			Dytiscidae	Coleoptera
Aeolus			Elateridae	Coleoptera
Ampedus			Elateridae	Coleoptera
Ctenicera			Elateridae	Coleoptera
			Elateridae	Coleoptera
			Elateridae	Coleoptera
			Elateridae	Coleoptera
			Elateridae	Coleoptera
			Elateridae	Coleoptera
			Elateridae	Coleoptera
			Elateridae	Coleoptera
			Elateridae	Coleoptera

Lacon	*discoidea*		Elateridae	Coleoptera
Lacon	*marmorata*		Elateridae	Coleoptera
Melanotus			Elateridae	Coleoptera
Aphorista	*vittata*		Endomychidae	Coleoptera
			Endomychidae	Coleoptera
			Endomychidae	Coleoptera
Tritoma	*buguttata*		Erotylidae	Coleoptera
			Eucinetidae	Coleoptera
			Heteroceridae	Coleoptera
			Histeridae	Coleoptera
			Histeridae	Coleoptera
			Histeridae	Coleoptera
			Histeridae	Coleoptera
			Hydrophilidae	Coleoptera
			Laemophloeidae	Coleoptera
Ellychnia	*autumnalis*		Lampyridae	Coleoptera
Photinus			Lampyridae	Coleoptera
			Latridiidae	Coleoptera
			Latridiidae	Coleoptera
			Leiodidae	Coleoptera
Calopteron	*reticulatum*		Lycidae	Coleoptera
Dircaea	*liturata*		Melandryidae	Coleoptera
Dircaea	*liurata*		Melandryidae	Coleoptera
Melandrya	*striata*		Melandryidae	Coleoptera
			Melandryidae	Coleoptera
Glipa	*bidentata*		Mordellidae	Coleoptera
			Mordellidae	Coleoptera
			Mordellidae	Coleoptera
			Mordellidae	Coleoptera
			Mycetophagidae	Coleoptera
Glischrochilus	*sanguinolentus*		Nitidulidae	Coleoptera
			Nitidulidae	Coleoptera
			Nitidulidae	Coleoptera
			Nitidulidae	Coleoptera
			Nitidulidae	Coleoptera
			Nitidulidae	Coleoptera
			Nitidulidae	Coleoptera
Pedilus			Pedilidae	Coleoptera
Dendroides	*canadensis*		Pyrochroidae	Coleoptera
Neopyrochroa	*flabellata*		Pyrochroidae	Coleoptera
Anomala	*orientalis*		Scarabaeidae	Coleoptera
Aphodius	*rubripennis*		Scarabaeidae	Coleoptera
Aphodius	*rusicola*		Scarabaeidae	Coleoptera
Aphodius	*stercorosus*		Scarabaeidae	Coleoptera
Ataenius	*imbricatus*		Scarabaeidae	Coleoptera
Ataenius	*strigatus*		Scarabaeidae	Coleoptera
Copris	*minutus*		Scarabaeidae	Coleoptera
Cyclocephala	*borealis*		Scarabaeidae	Coleoptera
Dialytellus	*dialytoides*		Scarabaeidae	Coleoptera
Dialytes	*striatulus*		Scarabaeidae	Coleoptera

Dialytes	*truncatus*		Scarabaeidae	Coleoptera
Dichelonyx	*diluta*		Scarabaeidae	Coleoptera
Dichelonyx	*elongata*		Scarabaeidae	Coleoptera
Euphoria	*fulgida*		Scarabaeidae	Coleoptera
Maladera	*castanea*		Scarabaeidae	Coleoptera
Nipponoserica	*peregrina*		Scarabaeidae	Coleoptera
Onthophagus	*hecate*		Scarabaeidae	Coleoptera
Onthophagus	*orpheus*		Scarabaeidae	Coleoptera
Pelodnota	*punctata*		Scarabaeidae	Coleoptera
Phyllophaga	*anxia*		Scarabaeidae	Coleoptera
Phyllophaga	*drakii*		Scarabaeidae	Coleoptera
Phyllophaga	*futilis*		Scarabaeidae	Coleoptera
Phyllophaga	*quercus*		Scarabaeidae	Coleoptera
Phyllophaga			Scarabaeidae	Coleoptera
Popillia	*japonica*		Scarabaeidae	Coleoptera
Serica	*elusa*		Scarabaeidae	Coleoptera
Serica	*sericea*		Scarabaeidae	Coleoptera
Serica			Scarabaeidae	Coleoptera
Trichiotinus	*affinis*		Scarabaeidae	Coleoptera
Trox	*aequalis*		Scarabaeidae	Coleoptera
Trox	*hamatus*		Scarabaeidae	Coleoptera
			Scirtidae	Coleoptera
			Scydmaenidae	Coleoptera
Nicrophorus	*orbicollis*		Silphidae	Coleoptera
Nicrophorus	*pustulatus*		Silphidae	Coleoptera
			Staphylinidae	Coleoptera
			Staphylinidae	Coleoptera
			Staphylinidae	Coleoptera
			Staphylinidae	Coleoptera
			Staphylinidae	Coleoptera
			Staphylinidae	Coleoptera
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			Staphylinidae	Coleoptera
			Staphylinidae	Coleoptera
			Staphylinidae	Coleoptera
			Staphylinidae	Coleoptera
			Staphylinidae	Coleoptera
			Staphylinidae	Coleoptera
			Staphylinidae	Coleoptera
			Staphylinidae	Coleoptera
			Staphylinidae	Coleoptera
			Staphylinidae	Coleoptera
			Staphylinidae	Coleoptera
			Staphylinidae	Coleoptera
Synchroa	*punctate*		Synchroidae	Coleoptera
			Tenebrionidae	Coleoptera
Anaedus	*brunneus*		Tenebrionidae	Coleoptera

Centronopus	*calcarata*		Tenebrionidae	Coleoptera
Haplandrus	*fulvipes*		Tenebrionidae	Coleoptera
Platydema			Tenebrionidae	Coleoptera
Strongylium	*tenuicolle*		Tenebrionidae	Coleoptera
			Tenebrionidae	Coleoptera
			Tenebrionidae	Coleoptera
Xylopinus	*saperdioides*		Tenebrionidae	Coleoptera
			Throscidae	Coleoptera
			Throscidae	Coleoptera
Tenebroides			Trogossitidae	Coleoptera
			Anthomyiidae	Diptera
			Asilidae	Diptera
Bibio			Bibionidae	Diptera
Penthetria	*heteroptera*		Bibionidae	Diptera
			Bibionidae	Diptera
			Bombyliidae	Diptera
			Calliphoridae	Diptera
			Cecidomyiidae	Diptera
			Conopidae	Diptera
			Dolichopodidae	Diptera
			Dryomyzidae	Diptera
			Empididae	Diptera
			Muscidae	Diptera
			Oestridae	Diptera
Bittacomorpha	*clavipes*		Ptychopteridae	Diptera
			Rhagionidae	Diptera
			Sarcophagidae	Diptera
			Scathophagidae	Diptera
			Sciomyzidae	Diptera
			Stratiomyidae	Diptera
			Syrphidae	Diptera
			Tabanidae	Diptera
Chrysops			Tabanidae	Diptera
			Tachinidae	Diptera
			Tephritidae	Diptera
			Therevidae	Diptera
Antocha	*saxicola*		Tipulidae	Diptera
Ctenophora	*dorasalis*		Tipulidae	Diptera
Dactylolabis	*cubitalis*		Tipulidae	Diptera
Dolichopeza	*sayi*		Tipulidae	Diptera
Limnophila	*marcocera*		Tipulidae	Diptera
Limonia	*husonica*		Tipulidae	Diptera
Limonia	*immature*		Tipulidae	Diptera
Limonia	*liberta*		Tipulidae	Diptera
Limonia	*rostrata*		Tipulidae	Diptera
Limonia	*triocellata*		Tipulidae	Diptera
Nephrotoma	*alterna*		Tipulidae	Diptera
Nephrotoma	*eucera*		Tipulidae	Diptera
Nephrotoma	*ferruginae*		Tipulidae	Diptera
Pseudolimnophila	*inornata*		Tipulidae	Diptera

Pseudolimnophila	*luteipennis*		Tipulidae	Diptera
Tipula	*bicornis*		Tipulidae	Diptera
Tipula	*eluta*		Tipulidae	Diptera
Tipula	*furca*		Tipulidae	Diptera
Tipula	*hermannia*		Tipulidae	Diptera
Tipula	*loniventris*		Tipulidae	Diptera
Tipula	*sayi*		Tipulidae	Diptera
Tipula	*tricattata*		Tipulidae	Diptera
Tipula	*tricolor*		Tipulidae	Diptera
Trichocera			Trichoceridae	Diptera
			Ulidiidae	Diptera
			Xylomyidae	Diptera
			Corixidae	Heteroptera
			Cydnidae	Heteroptera
			Lygaeidae	Heteroptera
			Miridae	Heteroptera
			Pentatomidae	Heteroptera
Halyomorpha	*halys*		Pentatomidae	Heteroptera
			Reduviidae	Heteroptera
			Cercopidae	Homoptera
			Cicadellidae	Homoptera
Oncometopia	*orbona*		Cicadellidae	Homoptera
Bruchomorpha			Issidae	Homoptera
			Membracidae	Homoptera
				Hymenoptera
				Hymenoptera
				Hymenoptera
				Hymenoptera
Andrena	*bisalicis*		Andrenidae	Hymenoptera
Andrena	*bradleyi*		Andrenidae	Hymenoptera
Andrena	*carlini*		Andrenidae	Hymenoptera
Andrena	*carolina*		Andrenidae	Hymenoptera
Andrena	*caenothi*		Andrenidae	Hymenoptera
Andrena	*cressonii*		Andrenidae	Hymenoptera
Andrena	*forbesii*		Andrenidae	Hymenoptera
Andrena	*nivalis*		Andrenidae	Hymenoptera
Andrena	*nuda*		Andrenidae	Hymenoptera
Andrena	*rehni*		Andrenidae	Hymenoptera
Andrena	*thaspii*		Andrenidae	Hymenoptera
Andrena	*virginiana*		Andrenidae	Hymenoptera
Calliopsis	*andreniformis*		Andrenidae	Hymenoptera
Bombus	*bimaculatus*		Apidae	Hymenoptera
Bombus	*impatiens*		Apidae	Hymenoptera
Bombus	*perlexus*		Apidae	Hymenoptera
Bombus	*ternarius*		Apidae	Hymenoptera
Bombus	*vagans*		Apidae	Hymenoptera
Ceratina	*calcarata*		Apidae	Hymenoptera
Ceratina	*dupla*		Apidae	Hymenoptera
Nomada	*pygmaea*		Apidae	Hymenoptera
Xylocopa	*virginica*		Apidae	Hymenoptera

			Bethylidae	Hymenoptera
			Braconidae	Hymenoptera
			Chrysididae	Hymenoptera
Colletes	*inequalis*		Colletidae	Hymenoptera
Colletes	*thoracicus*		Colletidae	Hymenoptera
Hylaeus	*affinis*		Colletidae	Hymenoptera
Oxybelus			Crabronidae	Hymenoptera
Sphecius	*speciosus*		Crabronidae	Hymenoptera
			Diapriidae	Hymenoptera
			Evaniidae	Hymenoptera
			Formicidae	Hymenoptera
Augochlora	*pura*		Halictidae	Hymenoptera
Augochlorella	*aurata*		Halictidae	Hymenoptera
Halictus	*confusus*		Halictidae	Hymenoptera
Halictus	*ligatus*		Halictidae	Hymenoptera
Halictus	*rubicundus*		Halictidae	Hymenoptera
Lasioglossum	*abanci*		Halictidae	Hymenoptera
Lasioglossum	*acuminatum*		Halictidae	Hymenoptera
Lasioglossum	*atlanticum*		Halictidae	Hymenoptera
Lasioglossum	*cressonii*		Halictidae	Hymenoptera
Lasioglossum	*fuscipenne*		Halictidae	Hymenoptera
Lassioglossum	*admirandum*		Halictidae	Hymenoptera
Lasioglossum	*oblongum*		Halictidae	Hymenoptera
Lasioglossum	*albiventris*		Halictidae	Hymenoptera
Lasioglossum	*asteris*		Halictidae	Hymenoptera
Lasioglossum	*foxli*		Halictidae	Hymenoptera
Lasioglossum	*heteregnathum*		Halictidae	Hymenoptera
Lasioglossum	*illinoense*		Halictidae	Hymenoptera
Lasioglossum	*imitatum*		Halictidae	Hymenoptera
Lasioglossum	*pectorale*		Halictidae	Hymenoptera
Lasioglossum	*pilosum*		Halictidae	Hymenoptera
Lasioglossum	*rohweri*		Halictidae	Hymenoptera
Lasioglossum	*tegulare*		Halictidae	Hymenoptera
			Ichneimonidae	Hymenoptera
			Ichneimonidae	Hymenoptera
			Leucospidae	Hymenoptera
Anthidium	*oblongatum*		Megachilidae	Hymenoptera
Hoplitis	*producta*		Megachilidae	Hymenoptera
Lithurgus	*chrysurus*		Megachilidae	Hymenoptera
Megachile	*gemula*		Megachilidae	Hymenoptera
Megachile	*mendica*		Megachilidae	Hymenoptera
Megachile	*texana*		Megachilidae	Hymenoptera
Osmia	*atriventris*		Megachilidae	Hymenoptera
Osmia	*felti*		Megachilidae	Hymenoptera
Osmia	*pumila*		Megachilidae	Hymenoptera
Osmia	*albiventris*		Megachilidae	Hymenoptera
Osmia	*lignara*		Megachilidae	Hymenoptera
Dasymutilla	*vesta*		Mutillidae	Hymenoptera
Ephuta	*conchatem*		Mutillidae	Hymenoptera
Ephuta	*pauxilla*		Mutillidae	Hymenoptera

Myrmosa	*unicolor*		Mutillidae	Hymenoptera
Anoplius	*atrox*		Pompilidae	Hymenoptera
Anoplius	*depessipes*		Pompilidae	Hymenoptera
Anoplius	*marginatus*		Pompilidae	Hymenoptera
Auplopus	*architectus*		Pompilidae	Hymenoptera
Ceropales	*bipunctata*		Pompilidae	Hymenoptera
Dipogon	*papago*		Pompilidae	Hymenoptera
Episyron	*quinquenotatus*		Pompilidae	Hymenoptera
Priocnessus	*nebulosus*		Pompilidae	Hymenoptera
			Scoliidae	Hymenoptera
			Sphecidae	Hymenoptera
Tachysphex	*ferrugineus*		Sphecidae	Hymenoptera
			Tiphiidae	Hymenoptera
			Trigonalidae	Hymenoptera
Dolichovespula	*arenaria*		Vespidae	Hymenoptera
Dolichovespula	*maculata*		Vespidae	Hymenoptera
Eumenes	*fraternus*		Vespidae	Hymenoptera
Eumeninae			Vespidae	Hymenoptera
Monobia	*quadridens*		Vespidae	Hymenoptera
Parazumia	*symmorpha*		Vespidae	Hymenoptera
Polistes	*dominula*		Vespidae	Hymenoptera
Polistes	*fuscatus*		Vespidae	Hymenoptera
Vespa	*crabro*		Vespidae	Hymenoptera
Vespula	*maculifrons*		Vespidae	Hymenoptera
Vespula	*vidua*		Vespidae	Hymenoptera
Vespula	*flavopilosa*		Vespidae	Hymenoptera
			(Gelechioidea)	Lepidoptera
Acrolophus	*arcanellus*		Acrolophidae	Lepidoptera
Acrolophus	*popeanellus*		Acrolophidae	Lepidoptera
Machimia	*tentoriferella*		Amphisbatidae	Lepidoptera
Apatelodes	*torrefacta*		Apatelodidae	Lepidoptera
Olceclostera	*angelica*		Apatelodidae	Lepidoptera
Apantesis	*carolotta*		Arctiidae	Lepidoptera
Apantesis	*nais*		Arctiidae	Lepidoptera
Grammia	*figurata*		Arctiidae	Lepidoptera
Grammia	*virgo*		Arctiidae	Lepidoptera
Holomelina	*immaculata*		Arctiidae	Lepidoptera
Hyphantria	*cunea*		Arctiidae	Lepidoptera
Spilosoma	*congrua*		Arctiidae	Lepidoptera
Spilosoma	*latipennis*		Arctiidae	Lepidoptera
Spilosoma	*virginica*		Arctiidae	Lepidoptera
Cisseps	*fulvicollis*		Arctiidae	Lepidoptera
Cycnia	*oregonensis*		Arctiidae	Lepidoptera
Cycnia	*tenera*		Arctiidae	Lepidoptera
Halysidota	*tesselaris*		Arctiidae	Lepidoptera
Lophocampa	*caryae*		Arctiidae	Lepidoptera
Crambidia	*pallida*		Arctiidae	Lepidoptera
Hypoprepia	*miniata*		Arctiidae	Lepidoptera
Drepana	*arcuata*		Drepanidae	Lepidoptera
Drepana	*bilineata*		Drepanidae	Lepidoptera

Heliomata	*cycladata*		Geometridae	Lepidoptera
Cepphis	*armataria*		Geometridae	Lepidoptera
Metarranthis	*amyrisaria*		Geometridae	Lepidoptera
Metarranthis	*angularia*		Geometridae	Lepidoptera
Metarranthis	*duaria*		Geometridae	Lepidoptera
Metarranthis	*obfirmaria*		Geometridae	Lepidoptera
Plagodis	*alcoolaria*		Geometridae	Lepidoptera
Plagodis	*phlogosaria*		Geometridae	Lepidoptera
Plagodis	*pulveraria*		Geometridae	Lepidoptera
Plagodis	*serinaria*		Geometridae	Lepidoptera
Probole	*amicaria*		Geometridae	Lepidoptera
Euchlaena	*irraria*		Geometridae	Lepidoptera
Euchlaena	*johnsonaria*		Geometridae	Lepidoptera
Euchlaena	*marginaria*		Geometridae	Lepidoptera
Euchlaena	*muzaria*		Geometridae	Lepidoptera
Lytrosis	*unitaria*		Geometridae	Lepidoptera
Pero	*honestaria*		Geometridae	Lepidoptera
Pero	*morrisonaria*		Geometridae	Lepidoptera
Lomographa	*glomeraria*		Geometridae	Lepidoptera
Lomographa	*semiclarata*		Geometridae	Lepidoptera
Lomographa	*vestaliata*		Geometridae	Lepidoptera
Hypagyrtis	*unipunctata*		Geometridae	Lepidoptera
Aethalura	*intertexta*		Geometridae	Lepidoptera
Anavitrinella	*pampinaria*		Geometridae	Lepidoptera
Ectropis	*crepuscularia*		Geometridae	Lepidoptera
Epimecis	*hortaria*		Geometridae	Lepidoptera
Glena	*cognataria*		Geometridae	Lepidoptera
Iridopsis	*defectaria*		Geometridae	Lepidoptera
Campaea	*perlata*		Geometridae	Lepidoptera
Ennomos	*magnaria*		Geometridae	Lepidoptera
Ennomos	*subsignaria*		Geometridae	Lepidoptera
Homochlodes	*fritillaria*		Geometridae	Lepidoptera
Macaria	*aemulataria*		Geometridae	Lepidoptera
Macaria	*argillacearia*		Geometridae	Lepidoptera
Macaria	*bicolorata*		Geometridae	Lepidoptera
Macaria	*bisignata*		Geometridae	Lepidoptera
Macaria	*fissinotata*		Geometridae	Lepidoptera
Macaria	*granitata*		Geometridae	Lepidoptera
Macaria	*minorata*		Geometridae	Lepidoptera
Macaria	*signaria*		Geometridae	Lepidoptera
Eufidonia	*convergaria*		Geometridae	Lepidoptera
Melanolophia	*signataria*		Geometridae	Lepidoptera
Nacophora	*quernaria*		Geometridae	Lepidoptera
Antepione	*thisoaria*		Geometridae	Lepidoptera
Besma	*endropiaria*		Geometridae	Lepidoptera
Besma	*quercivoraria*		Geometridae	Lepidoptera
Caripeta	*angustiorata*		Geometridae	Lepidoptera
Eutrapela	*clemataria*		Geometridae	Lepidoptera
Nematocampa	*resistaria*		Geometridae	Lepidoptera
Prochoerodes	*lineola*		Geometridae	Lepidoptera

Tetracis	*cachexiata*		Geometridae	Lepidoptera
Tetracis	*crocalata*		Geometridae	Lepidoptera
Hethemia	*pistasciaria*		Geometridae	Lepidoptera
Nemoria	*bistriaria*		Geometridae	Lepidoptera
Nemoria	*mimosaria*		Geometridae	Lepidoptera
Eupithecia			Geometridae	Lepidoptera
Eulithis	*diversilineata*		Geometridae	Lepidoptera
Hydriomena	*transfigurata*		Geometridae	Lepidoptera
Rheumaptera	*prunivorata*		Geometridae	Lepidoptera
Costaconvexa	*centrostrigaria*		Geometridae	Lepidoptera
Orthonama	*obstipata*		Geometridae	Lepidoptera
Cyclophora	*pendulinaria*		Geometridae	Lepidoptera
Scopula	*limboundata*		Geometridae	Lepidoptera
Amblyscirtes	*vialis*		Hesperiidae	Lepidoptera
Anatrytone	*logan*		Hesperiidae	Lepidoptera
Ancyloxpha	*numitor*		Hesperiidae	Lepidoptera
Epargyreus	*clarus*		Hesperiidae	Lepidoptera
Erynnis	*icelus*		Hesperiidae	Lepidoptera
Erynnis	*juvenalis*		Hesperiidae	Lepidoptera
Erynnis	*baptisiae*		Hesperiidae	Lepidoptera
Euphyes	*vestris*		Hesperiidae	Lepidoptera
Hylephila	*phyleus*		Hesperiidae	Lepidoptera
Nastra	*lherminier*		Hesperiidae	Lepidoptera
Poanes	*hobomok*		Hesperiidae	Lepidoptera
Poanes	*zabulon*		Hesperiidae	Lepidoptera
Polites	*peckius*		Hesperiidae	Lepidoptera
Polites	*themistocles*		Hesperiidae	Lepidoptera
Polites	*origenes*		Hesperiidae	Lepidoptera
Pompeius	*verna*		Hesperiidae	Lepidoptera
Wallengrenis	*egeremet*		Hesperiidae	Lepidoptera
Malacosoma	*americanum*		Lasiocampidae	Lepidoptera
Malacosoma	*disstria*		Lasiocampidae	Lepidoptera
Phyllodema	*americana*		Lasiocampidae	Lepidoptera
Tolype	*velleda*		Lasiocampidae	Lepidoptera
Adoneta	*spinuloides*		Limacodidae	Lepidoptera
Apoda	*biguttata*		Limacodidae	Lepidoptera
Euclea	*delphinii*		Limacodidae	Lepidoptera
Lithacodes	*fasciola*		Limacodidae	Lepidoptera
Prolimacodes	*badia*		Limacodidae	Lepidoptera
Sibine	*stimulea*		Limacodidae	Lepidoptera
Tortricida	*pallida*		Limacodidae	Lepidoptera
Tortricida	*testacea*		Limacodidae	Lepidoptera
Satyrium	*calanus*		Lycaenidae	Lepidoptera
Strymon	*melinus*		Lycaenidae	Lepidoptera
Everes	*comyntas*		Lycaenidae	Lepidoptera
Celastrina	*ladon*		Lycaenidae	Lepidoptera
Celastrina	*neglecta*		Lycaenidae	Lepidoptera
Dasychira	*obliquata*		Lymantriidae	Lepidoptera
Lymantria	*dispar*		Lymantriidae	Lepidoptera
Orgyia	*leucostigma*		Lymantriidae	Lepidoptera

Lithacodia	*albidula*		Noctuidae	Lepidoptera
Lithacodia	*muscosula*		Noctuidae	Lepidoptera
Maliattha	*synchitis*		Noctuidae	Lepidoptera
Pseudeustrotia	*carneola*		Noctuidae	Lepidoptera
Thioptera	*nigrofimbria*		Noctuidae	Lepidoptera
Acronicta	*afflicta*		Noctuidae	Lepidoptera
Acronicta	*americana*		Noctuidae	Lepidoptera
Acronicta	*dactylina*		Noctuidae	Lepidoptera
Acronicta	*hasta*		Noctuidae	Lepidoptera
Acronicta	*increta*		Noctuidae	Lepidoptera
Acronicta	*interrupta*		Noctuidae	Lepidoptera
Acronicta	*lobeliae*		Noctuidae	Lepidoptera
Acronicta	*modica*		Noctuidae	Lepidoptera
Acronicta	*noctivaga*		Noctuidae	Lepidoptera
Acronicta	*sperata*		Noctuidae	Lepidoptera
Acronicta	*tritona*		Noctuidae	Lepidoptera
Polygrammate	*hebraeicum*		Noctuidae	Lepidoptera
Simyra	*insularis*		Noctuidae	Lepidoptera
Eudryas	*unio*		Noctuidae	Lepidoptera
Amphipyra	*pyramidoides*		Noctuidae	Lepidoptera
Amphipyra	*tragopoginis*		Noctuidae	Lepidoptera
Athetis	*miranda*		Noctuidae	Lepidoptera
Callopistria	*mollissima*		Noctuidae	Lepidoptera
Chytonix	*palliatricula*		Noctuidae	Lepidoptera
Condica	*vecors*		Noctuidae	Lepidoptera
Cosmia	*calami*		Noctuidae	Lepidoptera
Elaphria	*cornutinis*		Noctuidae	Lepidoptera
Euplexia	*benesimilis*		Noctuidae	Lepidoptera
Lemmeria	*digitalis*		Noctuidae	Lepidoptera
Luperina	*passer*		Noctuidae	Lepidoptera
Papaipema	*rutila*		Noctuidae	Lepidoptera
Phlogophora	*iris*		Noctuidae	Lepidoptera
Phosphila	*miselioides*		Noctuidae	Lepidoptera
Phosphila	*turbulenta*		Noctuidae	Lepidoptera
Platyperigea	*multifera*		Noctuidae	Lepidoptera
Spodoptera	*frugiperda*		Noctuidae	Lepidoptera
Spodoptera	*ornithogalli*		Noctuidae	Lepidoptera
Allotria	*elonympha*		Noctuidae	Lepidoptera
Argyrostrotis	*anilis*		Noctuidae	Lepidoptera
Caenurgina	*crassiuscula*		Noctuidae	Lepidoptera
Catocala	*ilia*		Noctuidae	Lepidoptera
Catocala	*palaeogama*		Noctuidae	Lepidoptera
Drasteria	*grandirena*		Noctuidae	Lepidoptera
Ledaea	*perditalis*		Noctuidae	Lepidoptera
Mocis	*texana*		Noctuidae	Lepidoptera
Pangrapta	*decoralis*		Noctuidae	Lepidoptera
Panopoda	*rufimargo*		Noctuidae	Lepidoptera
Parallelia	*bistriaris*		Noctuidae	Lepidoptera
Phoberia	*atomaris*		Noctuidae	Lepidoptera
Phyprosopus	*callitrichoides*		Noctuidae	Lepidoptera

Zale	*aeruginosa*		Noctuidae	Lepidoptera
Zale	*helata*		Noctuidae	Lepidoptera
Zale	*lunifera*		Noctuidae	Lepidoptera
Eucirroedia	*pampina*		Noctuidae	Lepidoptera
Eupsilia	*sidus*		Noctuidae	Lepidoptera
Lithophane	*grotei*		Noctuidae	Lepidoptera
Lithophane	*hemina*		Noctuidae	Lepidoptera
Lithophane	*innominata*		Noctuidae	Lepidoptera
Lithophane	*signosa*		Noctuidae	Lepidoptera
Lithophane	*unimoda*		Noctuidae	Lepidoptera
Metaxaglaea	*semitaria*		Noctuidae	Lepidoptera
Pyreferra	*hesperidago*		Noctuidae	Lepidoptera
Sunira	*bicolorago*		Noctuidae	Lepidoptera
Achatia	*distincta*		Noctuidae	Lepidoptera
Aletia	*oxygala*		Noctuidae	Lepidoptera
Crocigrapha	*normani*		Noctuidae	Lepidoptera
Egira	*alternans*		Noctuidae	Lepidoptera
Faronta	*diffusa*		Noctuidae	Lepidoptera
Homorthodes	*lindseyi*		Noctuidae	Lepidoptera
Lacanobia	*subjuncta*		Noctuidae	Lepidoptera
Lacinipolia	*renigera*		Noctuidae	Lepidoptera
Leucania	*insueta*		Noctuidae	Lepidoptera
Leucania	*lapidaria*		Noctuidae	Lepidoptera
Leucania	*linda*		Noctuidae	Lepidoptera
Leucania	*linita*		Noctuidae	Lepidoptera
Leucania	*phragmitidicola*		Noctuidae	Lepidoptera
Leucania	*ursula*		Noctuidae	Lepidoptera
Morrisonia	*confusa*		Noctuidae	Lepidoptera
Morrisonia	*evicta*		Noctuidae	Lepidoptera
Morrisonia	*latex*		Noctuidae	Lepidoptera
Nephelodes	*minians*		Noctuidae	Lepidoptera
Orthodes	*cynica*		Noctuidae	Lepidoptera
Orthodes	*goodelli*		Noctuidae	Lepidoptera
Orthodes	*majuscula*		Noctuidae	Lepidoptera
Orthosia	*alurina*		Noctuidae	Lepidoptera
Orthosia	*garmani*		Noctuidae	Lepidoptera
Orthosia	*hibisci*		Noctuidae	Lepidoptera
Orthosia	*revicta*		Noctuidae	Lepidoptera
Orthosia	*rubescens*		Noctuidae	Lepidoptera
Polia	*detracta*		Noctuidae	Lepidoptera
Polia	*purpurissata*		Noctuidae	Lepidoptera
Protorthodes	*oviduca*		Noctuidae	Lepidoptera
Pseudaletia	*unipuncta*		Noctuidae	Lepidoptera
Spiramater	*grandis*		Noctuidae	Lepidoptera
Spiramater	*lutra*		Noctuidae	Lepidoptera
Trichordestra	*legitima*		Noctuidae	Lepidoptera
Ulolonche	*culea*		Noctuidae	Lepidoptera
Ulolonche	*modesta*		Noctuidae	Lepidoptera
Helicoverpa	*zea*		Noctuidae	Lepidoptera
Bleptina	*caradrinalis*		Noctuidae	Lepidoptera

Chytolita	*morbidalis*		Noctuidae	Lepidoptera
Idia	*aemula*		Noctuidae	Lepidoptera
Idia	*americalis*		Noctuidae	Lepidoptera
Idea	*laurenti*		Noctuidae	Lepidoptera
Idia	*rotundalis*		Noctuidae	Lepidoptera
Lascoria	*ambigualis*		Noctuidae	Lepidoptera
Macrochilo	*absorptalis*		Noctuidae	Lepidoptera
Macrochilo	*orciferalis*		Noctuidae	Lepidoptera
Palthis	*angulalis*		Noctuidae	Lepidoptera
Palthis	*asopialis*		Noctuidae	Lepidoptera
Phalaenophana	*pyramusalis*		Noctuidae	Lepidoptera
Phalaenostola	*larentioides*		Noctuidae	Lepidoptera
Phalaenostola	*metonalis*		Noctuidae	Lepidoptera
Renia	*discoloralis*		Noctuidae	Lepidoptera
Renis	*factiosalis*		Noctuidae	Lepidoptera
Renia	*flavipunctalis*		Noctuidae	Lepidoptera
Renis	*salusalis*		Noctuidae	Lepidoptera
Renia	*sobrialis*		Noctuidae	Lepidoptera
Tetanolita	*floridana*		Noctuidae	Lepidoptera
Zanclognatha	*cruralis*		Noctuidae	Lepidoptera
Zanclognatha	*laevigata*		Noctuidae	Lepidoptera
Zanclognatha	*lituralis*		Noctuidae	Lepidoptera
Zanclognatha	*ochreipennis*		Noctuidae	Lepidoptera
Bomolocha	*baltimoralis*		Noctuidae	Lepidoptera
Bomolocha	*manalis*		Noctuidae	Lepidoptera
Plathypena	*scabra*		Noctuidae	Lepidoptera
Spargaloma	*sexpunctata*		Noctuidae	Lepidoptera
Abagrotis	*alternata*		Noctuidae	Lepidoptera
Abagrotis	*anchocelioides*		Noctuidae	Lepidoptera
Agrotis	*ipsilon*		Noctuidae	Lepidoptera
Cerastis	*fishii*		Noctuidae	Lepidoptera
Dichagyris	*acclivis*		Noctuidae	Lepidoptera
Euxoa	*messoria*		Noctuidae	Lepidoptera
Feltia	*herilis*		Noctuidae	Lepidoptera
Feltia	*jaculifera*		Noctuidae	Lepidoptera
Feltia	*tricosa*		Noctuidae	Lepidoptera
Feltia	*geniculata*		Noctuidae	Lepidoptera
Lycophotia	*phyllophora*		Noctuidae	Lepidoptera
Noctua	*pronuba*		Noctuidae	Lepidoptera
Ochropleura	*implecta*		Noctuidae	Lepidoptera
Xestia	*dolosa*		Noctuidae	Lepidoptera
Xestia	*dilucida*		Noctuidae	Lepidoptera
Xestia	*normaniana*		Noctuidae	Lepidoptera
Xestia	*smithii*		Noctuidae	Lepidoptera
Nola	*cilicoides*		Noctuidae	Lepidoptera
Charadra	*deridens*		Noctuidae	Lepidoptera
Colocasia	*propinquilinea*		Noctuidae	Lepidoptera
Anagrapha	*falcifera*		Noctuidae	Lepidoptera
Autographa	*precationis*		Noctuidae	Lepidoptera
Copivaleria	*grotei*		Noctuidae	Lepidoptera

Psaphida	*resumens*		Noctuidae	Lepidoptera
Melanomma	*auricinctaria*		Noctuidae	Lepidoptera
Baileya	*australis*		Noctuidae	Lepidoptera
Heterocampa	*guttivitta*		Notodontidae	Lepidoptera
Hyperaeschra	*georgica*		Notodontidae	Lepidoptera
Macrurocampa	*marthesia*		Notodontidae	Lepidoptera
Schizura	*unicornis*		Notodontidae	Lepidoptera
Gluphisia	*septentrionis*		Notodontidae	Lepidoptera
Nadata	*gibbosa*		Notodontidae	Lepidoptera
Peridea	*angulosa*		Notodontidae	Lepidoptera
Peridea	*ferruginea*		Notodontidae	Lepidoptera
Symmerista	*canicosta*		Notodontidae	Lepidoptera
Datana	*angusii*		Notodontidae	Lepidoptera
Datana	*drexelii*		Notodontidae	Lepidoptera
Datana	*major*		Notodontidae	Lepidoptera
Cercyonia	*pegala*		Nymphalidae	Lepidoptera
Danaus	*plexippus*		Nymphalidae	Lepidoptera
Enodia	*anthedon*		Nymphalidae	Lepidoptera
Junonia	*coenia*		Nymphalidae	Lepidoptera
Limenitis	*arthemis*		Nymphalidae	Lepidoptera
Limenitis	*archippus*		Nymphalidae	Lepidoptera
Megisto	*cymela*		Nymphalidae	Lepidoptera
Nymphalis	*antiopa*		Nymphalidae	Lepidoptera
Nymphalis	*milberti*		Nymphalidae	Lepidoptera
Phyciodes	*tharos*		Nymphalidae	Lepidoptera
Polygonia	*interrogationis*		Nymphalidae	Lepidoptera
Polygonia	*comma*		Nymphalidae	Lepidoptera
Satyrodes	*appalachia*		Nymphalidae	Lepidoptera
Speyeria	*cybele*		Nymphalidae	Lepidoptera
Speyeria	*aphrodite*		Nymphalidae	Lepidoptera
Vanessa	*virginiensis*		Nymphalidae	Lepidoptera
Vanessa	*atalanta*		Nymphalidae	Lepidoptera
Battus	*philenor*		Papilionidae	Lepidoptera
Papilio	*polyxenes*		Papilionidae	Lepidoptera
Papilio	*glaucus*		Papilionidae	Lepidoptera
Papilio	*troilus*		Papilionidae	Lepidoptera
Pieris	*rapae*		Pieridae	Lepidoptera
Colias	*philodice*		Pieridae	Lepidoptera
Colias	*eurytheme*		Pieridae	Lepidoptera
			Pyralidae	Lepidoptera
Urola	*nivalis*		Pyralidae	Lepidoptera
Desmia	*funeralis*		Pyralidae	Lepidoptera
Nomophila	*nearctica*		Pyralidae	Lepidoptera
Dryocampa	*rubicunda*		Saturniidae	Lepidoptera
Automeris	*io*		Saturniidae	Lepidoptera
Antheraea	*polyphemus*		Saturniidae	Lepidoptera
Synanthedon	*acerni*		Sesiidae	Lepidoptera
Deidamia	*inscripta*		Sphingidae	Lepidoptera
Paonias	*excaecatus*		Sphingidae	Lepidoptera
Ceratomia	*undulosa*		Sphingidae	Lepidoptera

Lapara	*coniferarum*		Sphingidae	Lepidoptera
Sphinx	*gordius*		Sphingidae	Lepidoptera
Pseudothyatira	*cymatophoroides*		Thyatiridae	Lepidoptera
			Tortricidae	Lepidoptera
Atteva	*punctella*		Yponomeutidae	Lepidoptera
Pyromorpha	*dimitiata*		Zygaenidae	Lepidoptera
Merope	*tuber*		Merpeidae	Mecoptera
Panorpa			Panorpidae	Mecoptera
Chauliodes	*pectinicornis*		Corydalidae	Megaloptera
Chauliodes	*rastricornis*		Corydalidae	Megaloptera
Corydalus	*cornutus*		Corydalidae	Megaloptera
Sialis			Sialidae	Megaloptera
			Chrysopidae	Neuroptera
			Hemerobiidae	Neuroptera
			Mantisidae	Neuroptera
			Myrmeleontidae	Neuroptera
Anax	*junius*		Aeshnidae	Odonata
Calopteryx	*maculata*		Calopterygidae	Odonata
Amphiagrion	*saucium*		Coenagrioidae	Odonata
Argia	*fumipennis*		Coenagrioidae	Odonata
Argia	*moesta*		Coenagrioidae	Odonata
Argia	*apicalis*		Coenagrioidae	Odonata
Argia	*translata*		Coenagrioidae	Odonata
Enallagma	*aspersum*		Coenagrioidae	Odonata
Enallagma	*civile*		Coenagrioidae	Odonata
Enallagma	*hageni*		Coenagrioidae	Odonata
Enallagma	*exsulans*		Coenagrioidae	Odonata
Enallagma	*signatum*		Coenagrioidae	Odonata
Ischnura	*posita*		Coenagrioidae	Odonata
Ischnura	*ramburii*		Coenagrioidae	Odonata
Ischnura	*verticalis*		Coenagrioidae	Odonata
Epitheca	*princeps*		Corduliidae	Odonata
Epitheca	*cynosura*		Corduliidae	Odonata
Dromogomphus	*spinosus*		Gomphidae	Odonata
Gomphus	*exilis*		Gomphidae	Odonata
Lestes	*inaequalis*		Lestidae	Odonata
Lestes	*rectangularis*		Lestidae	Odonata
Lestes	*vigilax*		Lestidae	Odonata
Celithemis	*elisa*		Libellulidae	Odonata
Erythemis	*simplicicollis*		Libellulidae	Odonata
Leucorrhinia	*intacta*		Libellulidae	Odonata
Libellula	*cyanea*		Libellulidae	Odonata
Libellula	*incesta*		Libellulidae	Odonata
Libellula	*luctuosa*		Libellulidae	Odonata
Libellula	*puchella*		Libellulidae	Odonata
Pachydiplax	*longipennis*		Libellulidae	Odonata
Plathemis	*lydia*		Libellulidae	Odonata
Sympetrum	*rubicundulum*		Libellulidae	Odonata
Sympetrum	*vicinum*		Libellulidae	Odonata
Tramea	*abdominalis*		Libellulidae	Odonata

			Acrididae	Orthoptera
			Gryllidae	Orthoptera
Phyllopalpus			Gryllidae	Orthoptera
			Tetrigidae	Orthoptera
Scudderia	*furcata*		Tettigoniidae	Orthoptera
Scudderia	*septentrionalis*		Tettigoniidae	Orthoptera
				Plecoptera
				Trichoptera
Macrostemum	*zebratum*		Hyrdopsychidae	Trichoptera

Macroinvertebrate Diversity in Metal Contaminated Ponds of the Lehigh Gap Refuge

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Abstract

The area surrounding Palmerton, PA was heavily polluted by two zinc smelting plants that were in operation for almost 100 years, resulting in severe deforestation of the northern slope of the Kittatinny Ridge of Blue Mountain along the Lehigh River. A 2000 acre zone was declared a Superfund site, the largest east of the Mississippi River, when operations ceased in the 1970's. The purpose of this project was to establish an inventory of the macroinvertebrate populations in three ponds affected by heavy metal contamination that are located within the refuge. Each of the three pond sites were sampled with 1000 µm 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 Shannon Index values indicate that Mallard Pond is the most diverse and Wood Duck Pond has the most even species distribution. The Family Biotic Index ranking of Mallard was fairly poor, whereas it was good for the other two ponds.

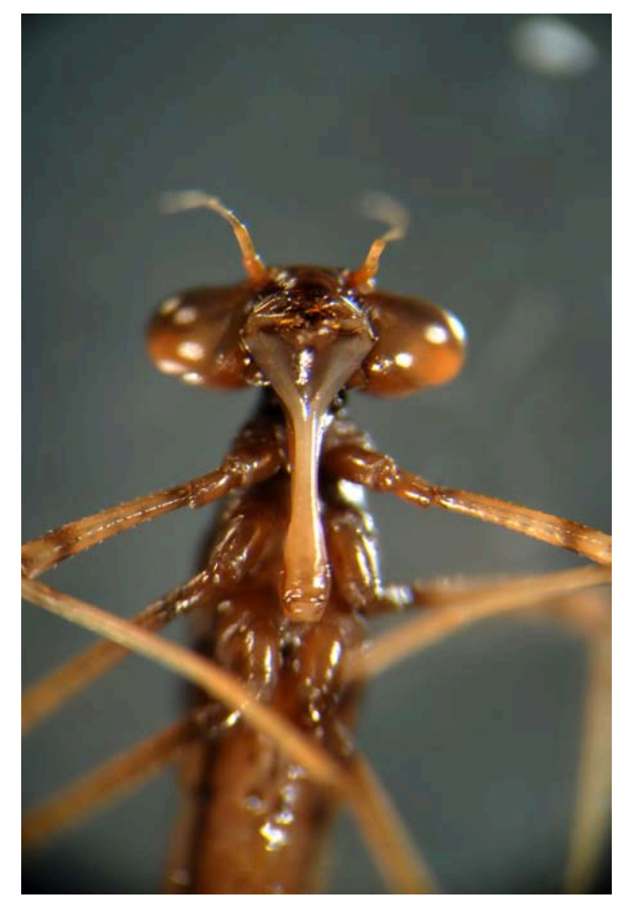
Introduction

Two zinc smelting plants were in operation in Palmerton, PA for almost 100 years, causing severe deforestation of the northern slope of the Kittatinny Ridge of Blue Mountain[1]. A 2000 acre zone was declared a Superfund site, the largest east of the Mississippi River. In 2003 the non-profit Wildlife Information Center purchased 750 acres west of the Lehigh River, began habitat restoration and management efforts, and initiated baseline ecological studies on the refuge, in order to monitor change, measure success, and enhance these habitats for the future. The purpose of this project was to establish an inventory of the macroinvertebrate populations in three ponds affected by heavy metal contamination that are located within the refuge. My main objective is qualitative; I simply want to determine what macroinvertebrate taxa are found there. I will use this data to calculate the biodiversity indices of the three ponds. Biodiversity indices are useful in assessing pond water quality because different taxa are found in different water quality levels. Although the ponds are close to the smelting plants, they are not located downwind and so have not been as heavily bombarded as the rest of the mountainside. Therefore I expect the environmental damage to be minimal.

Experimental Method

Each of the three pond sites were sampled around the edges with 1000 µm mesh nets. We also used a canoe to sample from the center of the ponds using a bottom dredge sampler. These samples were placed in jars and taken back to the lab for separation. While in the canoe we also attached two other types of samplers to a line to be left out and collected later. The Hester-Dendy Sampler hangs suspended in the water column and is meant for invertebrates to attach themselves to it. The Periphyton Sampler floats on the surface, where algae and protozoans attach to its glass slides. These samplers gave us more variety in the type of samples that we were able to collect.

From 100 to 200 macroinvertebrates were sampled at each pond, yielding 25 to 50 different species. Macroinvertebrates were preserved in 70% ethanol and sorted. In a subsequent collection, invertebrates were sorted before being preserved in ethanol. This led to an increase in the number of individuals found and identified to family or genus and diversity measured using the Shannon and Hilsenhoff Family Biotic Indices.



Lestidae sp.

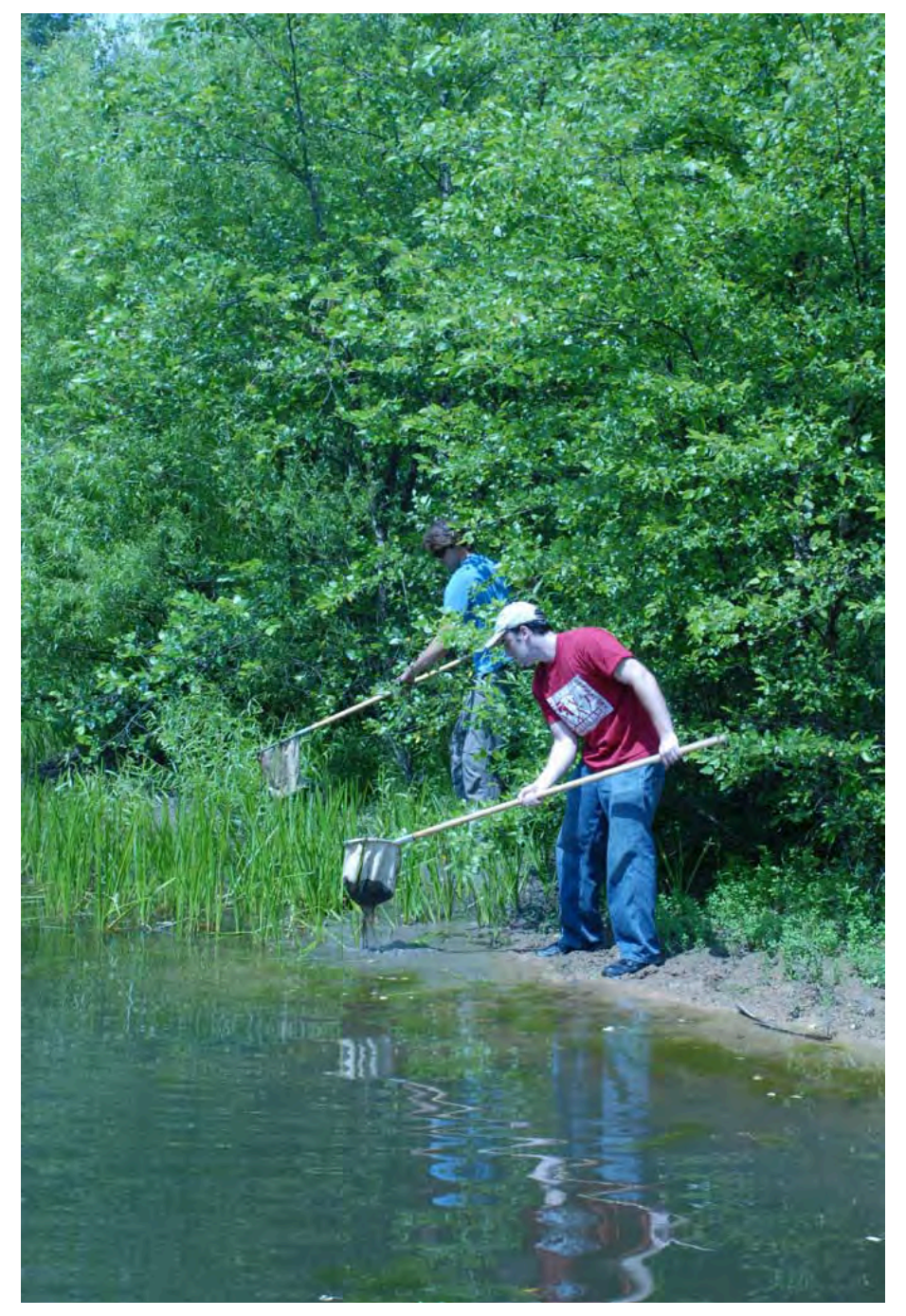


Table 1. Composition measures and statistical analysis for all ponds.

Composition Measures	Mallard	Kingfisher	Wood Duck
Total Number of Individuals	230	80	79
Total Taxa	49	25	29
Dominant Taxa	*Coenagrion*	*Corisella*	*Neoporus*
% Dominant Taxa	20.5	33.3	16.44
Shannon Diversity Index (H') (1)*	3.06	2.44	2.86
H' max	3.89	3.22	3.33
J (evenness) (2)*	.79	.76	.86
FBI Index (3)*	6.68	5.00	4.66
FBI Rank	Fairly Poor	Good	Good
# Very Intolerant Taxa (FBI ≤2)	3	1	0
% Individuals in Tolerant Taxa (FBI ≥5)	49.13	26.25	53.16

* (#) denotes equation

Baetidae sp.

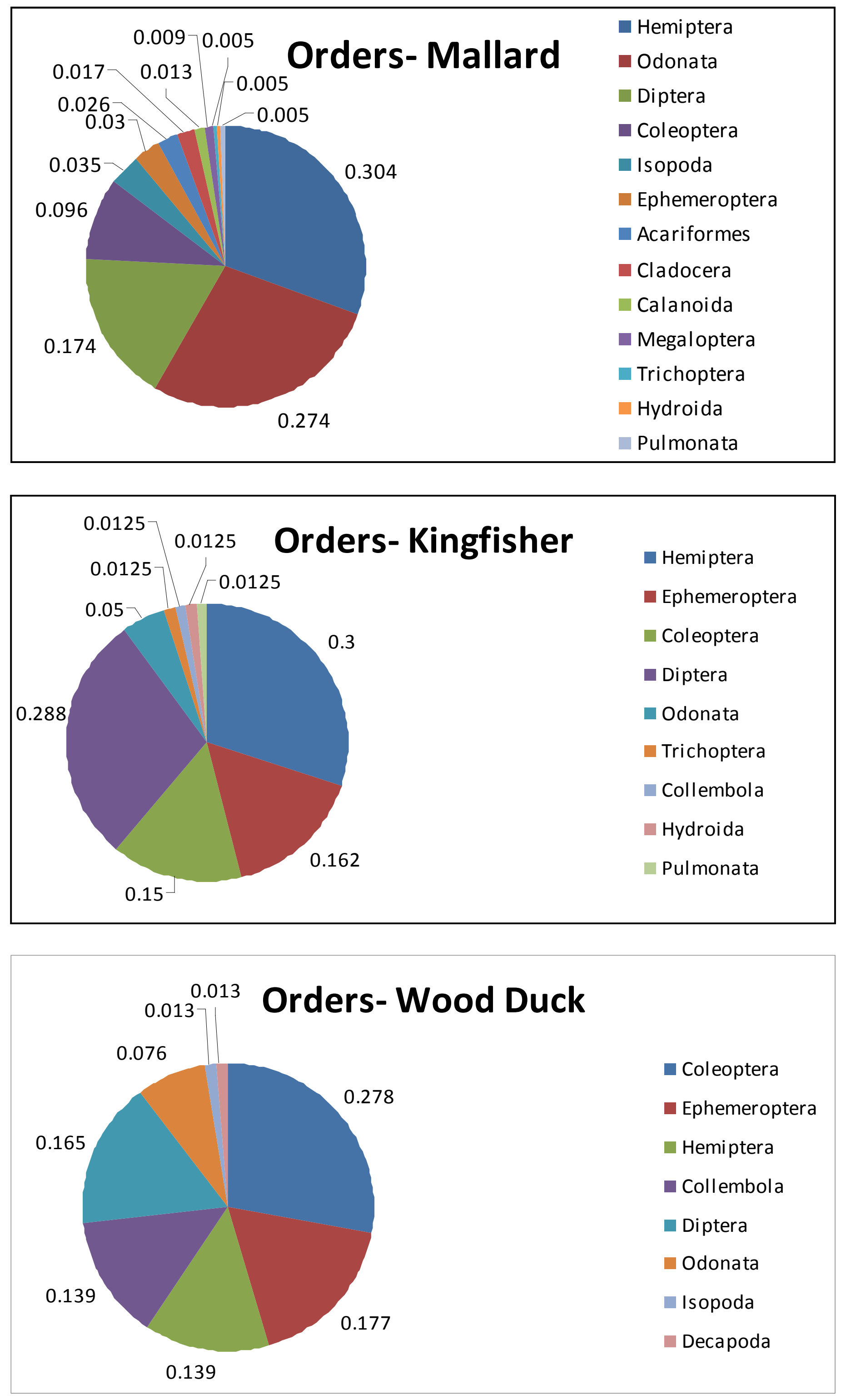


Figure 1. Percentage of individuals in each order.

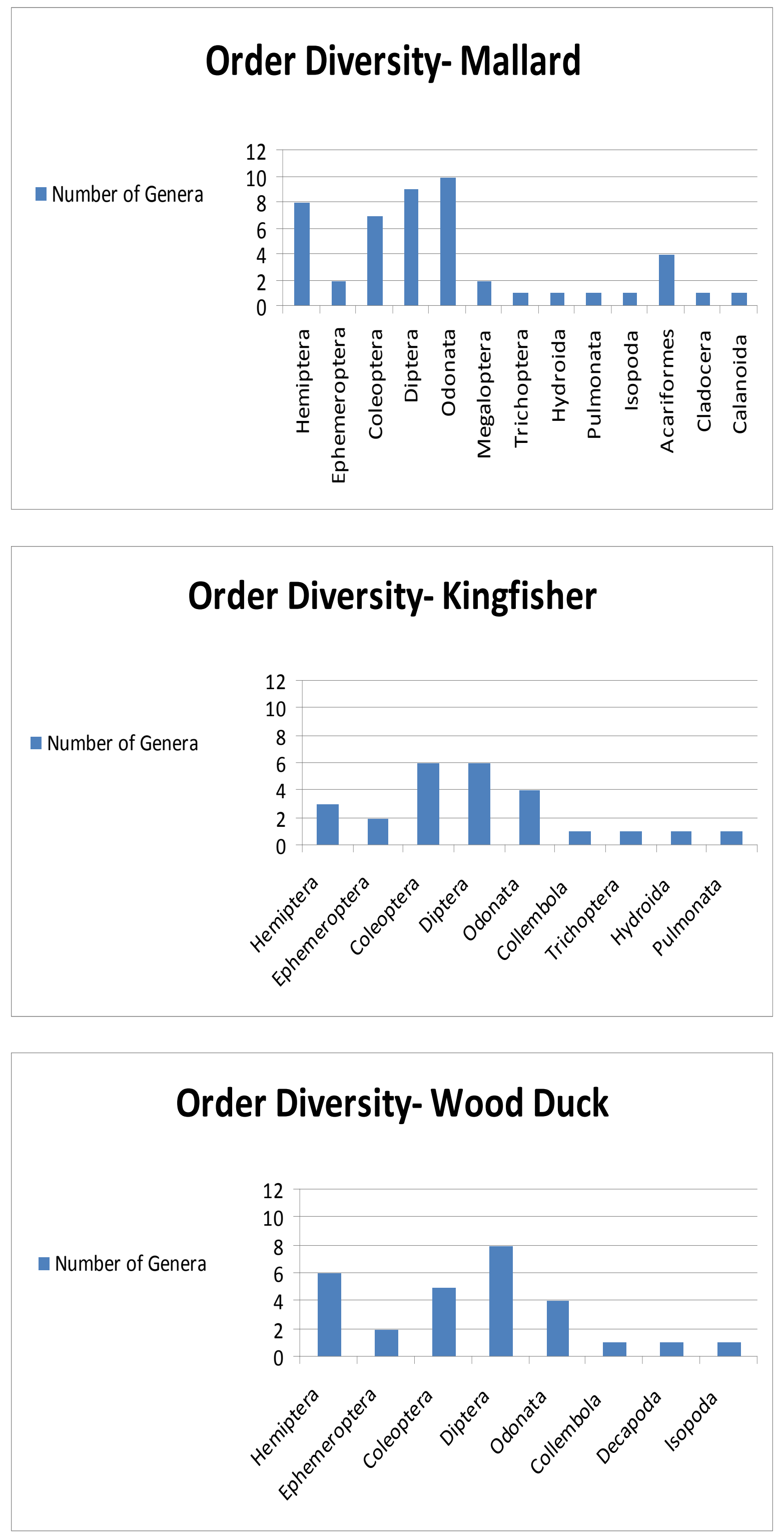


Figure 2. Number of genera represented in each order.

$$1.\ H' = -\sum_{i=1}^{S} p_i * \ln p_i$$

$$2.\ J = H'/\ln S$$

$$3.\ FBI = \sum_{i=1}^{S} (x_i * t_i / n)$$

Chironomidae sp.

Discussion

Figure 1 indicates that Mallard Pond is the most diverse of the three ponds. This result may be due to sampling technique, however; Mallard was the only pond sampled in which the specimens were not preserved before they were separated from the muck. It is also evident from Figure 1 that no one order is dominant across all three ponds, though Hemiptera is the most common in two ponds; it comprises about 30 percent of individuals in both Mallard and Kingfisher. Table 2 shows that the Hemiptera found in these two ponds are not equal; only three genera are found in Kingfisher whereas eight are found in Mallard. Mallard contains three orders that are not found in the other ponds, but that is also probably due to sampling technique.

Statistical analysis shows that Mallard is indeed the most diverse since it has the highest Shannon Diversity Index Ranking. Wood Duck has the highest J ranking, which is an indication of how evenly the individuals are spread among families. The Shannon Index is only moderately useful, though; it is calculated without regard to which taxa are present. The Family Biotic Index, adopted from the Hilsenhoff Index, assigns a tolerance value to each family and calculates a number based on the relative abundance of each family present[2]. This number falls on a scale of 1-10, with a 1 representing the highest water quality. Table 1 shows that only Mallard has poor water quality; both Kingfisher and Wood Duck are considered good. Neither of these ponds were sampled as well as Mallard, though, so their FBI ranking may decrease with a more thorough sample.

Ephemeroptera, the order of mayflies, is a good indicator of water quality[3]. Individuals in this order are generally intolerant of poor water, so bodies of water in which there is a large proportion of mayflies usually has a good ranking. Unfortunately, mayflies are less common in ponds than they are in streams. According to Menetrey *et al.*[3], only two genera are commonly found, *Caenis* (Caenidae) and *Cloeon* (Baetidae). Two genera were found in the ponds under study; one is *Caenis*, but the other is a different genera of Baetidae, *Paracloeodes.* Because of the limited availability of Ephemeroptera, the accuracy of the Family Biotic Index Rank (Table 1) is questionable for use in ponds.

Acknowledgements

We would like to thank Mr. Dan Kunkle, Director of the Lehigh Gap Nature Center, his assistance in providing a canoe for our use during field sampling. We would also like to thank the Moravian College SOAR Program, the Ervin J. Rokke Faculty-Student Research Endowment, and the Pennsylvania Wild Resource Conservation Fund for their financial support of this project.

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Appendix E-1

CURRENT STATE OF THE SOIL MICROFLORA AT THE PALMERTON, PA SUPERFUND SITE

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Abstract

Heavy metal concentrations of zinc, cadmium, copper and lead have significantly declined over the past 32 years in the O_2, A_1, and A_3 soil horizons within 2 km of the east-plant zinc (Zn) smelter located near Palmerton, PA. In a previous study Jordan and Lechevalier (1975) recorded up to 129,000 ppm of zinc, 1800 ppm of cadmium (Cd), 2150 ppm of copper (Cu) and 1900 ppm of lead (Pb) in the O_2 soil horizon of the most affected site. Current (2007) metal concentration in the O_2 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.

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_2 horizon of the most affected sites (*S1 and S2*). A strain of *Alcaligens eutrophus*, a bacteria classified by its ability to demonstrate plasmid-bound resistance to Co^{2+}, Ni^{2+}, Zn^{2+} and Cd^{2+} ions (Mergeay *et al*. 1985), was isolated from *S1* and *S2* soils.

Introduction

Located in Carbon County, Pennsylvania, near the Lehigh Gap, the borough of Palmerton has been the home to two zinc (Zn) smelting plants dating back to 1898. Since then, zinc sulfide ores smelted in this area resulted in exceedingly high concentrations of zinc (8%), cadmium (1500 ppm), copper (1200 ppm) and lead (1100 ppm) by dry weight in soils downwind of the smelters (Jordan and Lechevalier, 1975). Over the course of 90 years of smelting operations, emission estimates approaching 260,000 tons (t) of zinc, 3,300 t of cadmium, 8,600 t of lead (Beyer, 1988), forest fires, acid rain erosion and desiccation has resulted in defoliation of over 2,000 acres (USFW) of once densely forested land along Blue Mountain. The smelters ceased operations in the late 1970's and the affected mountainside became widely recognized as the largest EPA Superfund site east of the Mississippi River. Risk assessments and ecological remediation efforts under the direction of the U.S. Environmental Protection Agency, the Pennsylvania Department of Environmental Protection and non-profit organizations such as the Lehigh Gap Nature Center (LGNC) are underway in an attempt to restore and bring life back to the mountain.

A survey of soil microflora 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 concluded that the heaviest of Zn-contaminated soils experienced the greatest loss in total numbers of bacteria, fungi and actinomycetes. We propose a study to determine what changes microbial populations and communities have undergone since this study was undertaken near the termination of ore smelting activities near Palmerton, PA. It is well documented that microorganisms play key roles in determining soil fertility. It is, therefore, important to understand the changes in the microbial microflora in an area so heavily decimated by the smelting and subsequent deposition of heavy metals as it recovers through remediation efforts. Our goal was to follow as faithfully as possible the original Jordan and Lechevalier (1975) sampling protocol.

Materials and Methods

Site Selection and Sampling Methods

Seven sites along the Appalachian Trail, Blue Mountain, Pennsylvania were selected for sampling (Figures 1 and 2) in Summer 2007. Four sites (*S1*, *S2*, *S6* and *S7*) were selected for all

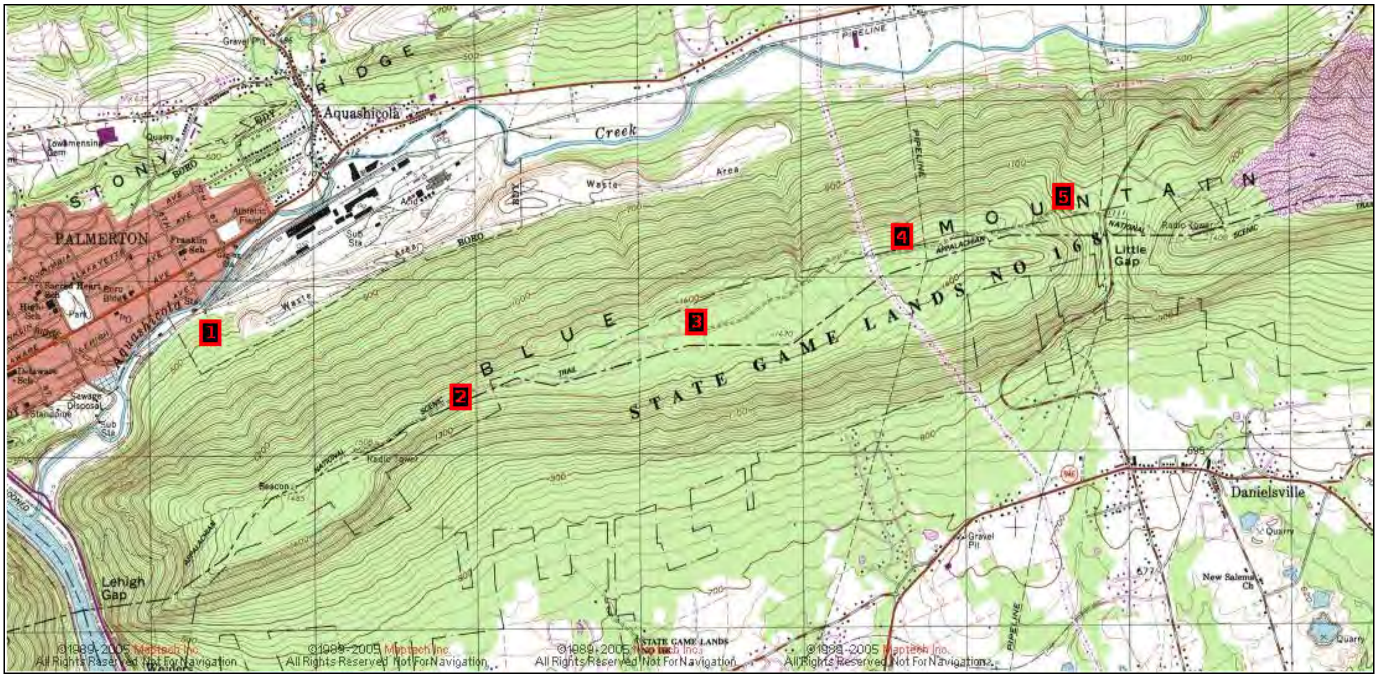

Figure 1. Sampling plots *S1*-*S5*. Microbial enumeration and metal analysis was conducted at *S1* (north facing, near lower slope) and *S2* (north facing, ridge-top). Sites 3 through 5 (*S3*-*S5)* were sampled solely for pH, % moisture and metal analyses.

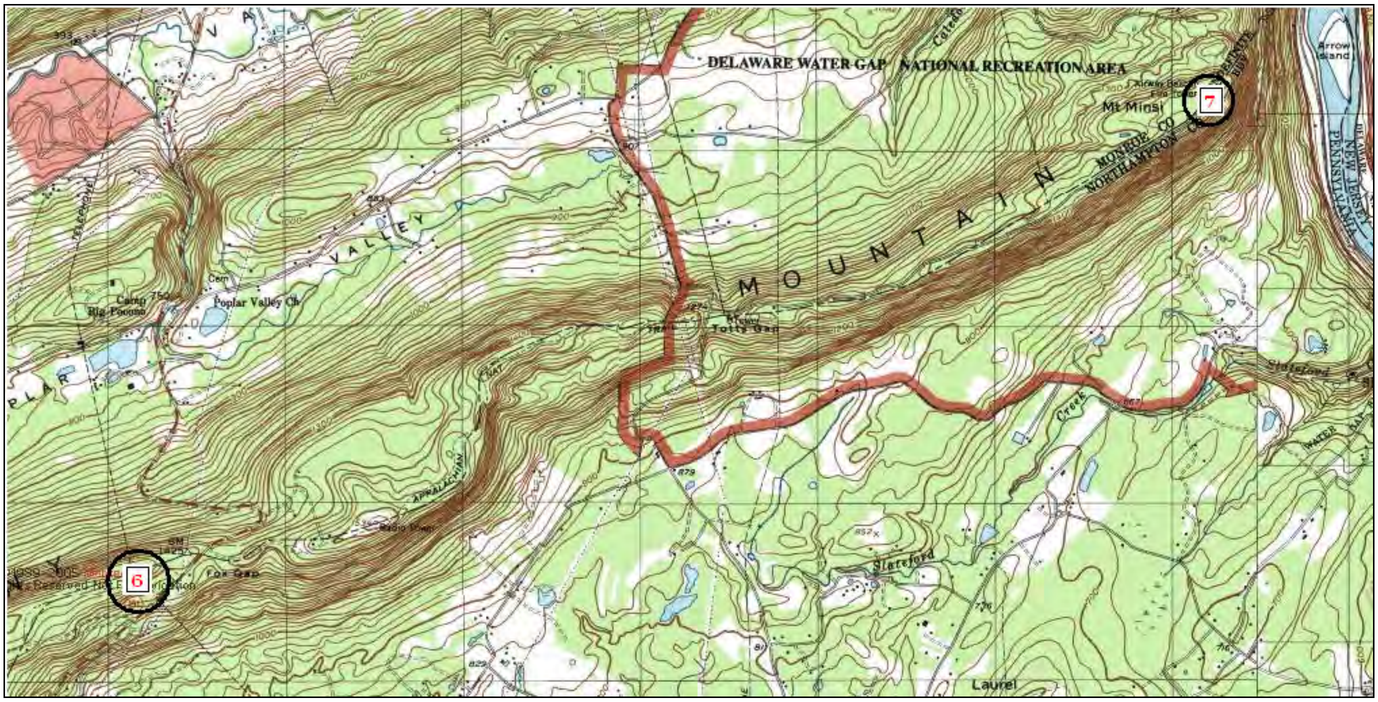

Figure 2. Sites *S6* at Fox Gap (north facing, distant lower slope) and *S7* at Delaware Water Gap (north facing, ridge-top) were used as control sites. These sites were located 40 and 46 km away from the former zinc smelter, respectively.

protocols (metal analysis and microbial microflora enumeration) while three sites (*S3*, *S4*, and *S5*) were excluded from microbial microflora enumeration. The "near" (affected) sites were located closest to the original smelters, at the base of the mountain (*S1*) and at the ridge top (*S2*). All soil samples were collected on the north face of the mountain, and progressed eastward from *S1* to *S5* in 1 km intervals. The "distant" (control) sites were located at the lower slope near Fox Gap (*S6*), and at the ridge top near the Delaware Water Gap (*S7*), located 40 km and 46 km away, respectively, from the original smelters. GPS coordinates were recorded at each site using a Magellan® Explorer 100 handheld GPS.

Four pits were excavated at each site using a square point shovel. Each pit measured approximately 0.5 m × 0.5 m, and varied in depths of up to 35 cm. At each pit, soil samples from the O_2 (partially decomposed leaf litter), A_1 (upper topsoil) and A_3 (lower topsoil/mineral soil transition) horizons were transferred aseptically into Fisherbrand ® 50 ml sterile centrifuge tubes. An alcohol-flamed, stainless steel spatula was used to perform the transfers.

Soil Analysis

Soil from each horizon (O, A_1, A_3) from two of the four pits, *P2* and *P4,* at each site (*S1* through *S7*) were separately combined for soil analysis. Soil moisture analysis was performed by weighing the soil samples before and after air-drying for 48 hours. Samples were subsequently forced through a 2 mm mesh screen and a portion of all samples were used to determine soil pH using an Accumet® Basic AB15 pH meter.

Heavy Metal Analysis

Soil analysis for heavy metal content was performed under the direction of Dr. Hank Edenborn (U.S. Department of Energy National Energy Technology Laboratory, 626 Cochrans Mill Road, Pittsburgh, PA 15236). The analytical method used was a close approximation of EPA Method 3050B, *"Acid Digestion of Sediments, Sludges and Soils."* This entailed digesting 1.0 g of soil with 2.5 ml of concentrated nitric acid and 10 ml of concentrated HCl, boiling/refluxing for 15 minutes, followed by filtration through Whatman #541 filter paper. The material collected on the filter was redigested (heat/reflux) with 5 ml concentrated HCl for 10-15 minutes until the filter paper dissolved. This mix was refiltered and the total volume was brought to 100 ml with deionized water. The four metals (Zn, Cd, Cu, Pb) were analyzed by inductively coupled plasma optical mass spectrometry (ICPMS).

Microbial Enumeration

Soil from sites 1, 2, 6 and 7 were subject to microbial enumeration. Soil from each horizon (O, A_1, A_3) from two of the four pits, *P1* and *P3,* at each site were combined together.

Soil dilutions were prepared within 24 hours using a dilution plate technique (Leboffe and Pierce, 2006). Six plates per dilution, per sample were asceptically spread onto petri dishes and incubated at 23°C. After 6 days of incubation, bacterial colonies and fungal colonies were enumerated.

Two sets of media, "original" (Jordan and Lechevalier 1975) and "new" (Leboffe and Pierce 2006) were used. The original set consisted of yeast-dextrose agar (*YDA*) for bacteria and a thin-Pablum[1] extract agar with 100μg/ml of neomycin (*T-PabN*) for fungal enumeration, respectively (Lechevalier 1968). The new set consisted of nutrient agar (*NA*) for bacteria and Sabouraud dextrose agar (*SDA*) with 20000.0 units of penicillin and 0.00004 g of streptomycin for fungal enumeration, respectively. Each media type in each set were thus replicated by a media type in the other set: *YDA* and *NA* were used enriched to enumerate for bacteria while *T-PabN* and *SDA* were used for fungal counts.

Bacterial Isolate Identification

Selected bacterial colonies were isolated and subcultured from enumeration plates from site *S1*. Mannitol salt agar (*MSA*), eosin methylene blue agar (*EMB*), and triple sugar iron agar slants (TSI) were used in selection for and differentiation of isolated bacterial colonies. Gram stains, spore stains, catalase tests with 3% H_2O_2 and oxidase tests using BBL® DrySlides were also performed when necessary. Colonies were isolated and then sub-cultured on Biolog Universal Growth (BUG™) agar with 5% sheep blood (BUG + B). A 25% sterile solution of maltose and/or thioglycolate was added to analyze for *Bacillus spp.* Bacterial identifications were performed using the Biolog MicroLog ™ Microbial ID/Characterization System.

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[1] Pablum brand mixed cereal was discontinued, and was therefore substituted by Gerber mixed grain cereal in this study. Nutritional values were comparable in both brands.

Results

Soil Heavy Metal Analysis

Jordan and Lechevalier (1975) reported exceedingly high levels of metals in the soils near the Palmerton smelters when compared to the more distant sites at Fox Gap and the Delaware Water Gap (Table 1). The near lower slope (*S1*) was the most affected site as it was closest to the smelter. Values of up to 129,000 ppm gram dry soil^{-1} of zinc were detected in the O_2 horizon in this area. Cadmium, copper and lead levels were also significantly higher at the near sites compared to the more distant sites, although soil metals at these sites, which are located more than 40 km from the smelters, were still elevated. Metal levels decreased with soil depth.

Currently (2007), however, the soil from the lower slope site (*S1*) exhibited a drastic decrease from the 129,000 ppm of zinc detected in 1975 to 4,438 ppm. Near ridge-top soils samples (*S2*) also showed a significant decrease in zinc from 33,700 ppm in 1975 to 5,312 ppm. Interestingly enough, copper and lead levels remain relatively high at the near ridge-top site.

Bacterial Abundance Results

Significantly lower bacterial populations (CFUs dry soil^{-1}) were observed in the O_2 and A_1 horizons at the near affected site (*S1*) in 1975 when compared to the distant control sample at site *S6* near Fox Gap (Figure 3, top left graph). The current data (2007) show that bacteria numbers in these horizons at the *S1* have recovered to the point that they are not significantly different from numbers seen at the control (*S6*) site (Figure 3, top right graph). Population counts in this horizon increased by approximately 50 times from the initial 2.5×10^5 CPUs dry soil^{-1} recorded in 1975. Similarly, the A_1 horizon exhibited an increase of nearly 20 times than previously recorded. A similar, although less dramatic pattern occurs between the near (*S2*) and distant (*S7*) ridge-top sites (Figure 3, bottom left and right graphs).

Fungal Abundance Results

In 1975 fungal counts at the near lower slope (*S1*) were marginally lower when compared to the distant control site (*S6*) with the greatest difference observed in the O_2 horizon while the A_3 horizon barley expressed any difference at all (Figure 4, top left graph). By 2007 fungal levels were insignificantly different between near and distant sites (Figure 4, top right graph). As previously observed for bacteria, the greatest effect was observed in the O horizon. When compared to the distant control site (*S7)*, ridge-top soil samples collected in 1975 were significantly lower in fungal counts in all three horizons. Over the last 32 years however, all three horizons demonstrated notable increases in fungal populations (Figure 4, lower graphs).

Identification of Bacterial Isolates

The most prominent identifiable species isolated from soil samples at *S1* included: *Staphylococcus sciuri*, *Chryseobacterium gleum/indologenes* (a flavobacterium commonly used in bioremediation), *Corynebacterium seminale,* and *Arthrobacter histidinolovorans* all of which are widespread in nature (Stepanovic *et al*. 2005; Yamaguchi and Yokoe 2000; Khamis *et al*. 2004; Holt *et al*. 1994). Other prominent species were *Rhizobium radiobacter*, a nitrogen fixing soil bacterium (Young 2001) and *Alcaligenes eutrophus*. Interestingly enough, *Alcaligenes eutrophus* has been characterized as the first gram-negative bacterium to show plasmid-bound resistance to cadmium and zinc (Mergeay 1985).

Table 1. Comparison of 1975 and 2007 of physical and heavy metal analyses in soils from sites near (*S1* and *S2*) and far (*S6* and *S7*) from the former Palmerton, PA zinc smelters.

1975 Soil Analyses

			Total metal content (ppm)[1]			
Horizon	**pH**	**% moisture**	**Zn**	**Cd**	**Cu**	**Pb**
Distant-ridge top (Site *S7*)						
O_2	4.0	55.4	650	8.0	34	362
A_1	3.8	42.4	225	3.0	18	152
A_3	3.7	27.7	74	2.7	11	22
Distant-lower slope (Site *S6*)						
O_2	4.1	52.3	570	6.0	26	287
A_1	3.6	37.1	110	3.0	18	113
A_3	3.9	21.7	44	8.5	13	22
Near-ridge top (Site *S2*)						
O_2	5.3	67.3	33700	1120	350	2250
A_1	5.5	71.7	22500	312	82	300
A_3	4.5	29.6	1310	12	8	40
Near-lower slope (Site *S1*)						
O_2	6.2	31.6	129000	1800	2150	1900
A_1	6.2	39.8	60700	750	400	1350
A_3	4.8	20.8	1750	15	16	55

2007 Soil Analyses

			Total metal content (ppm)[1]			
Horizon	**pH**	**% moisture**	**Zn**	**Cd**	**Cu**	**Pb**
Distant-ridge top (Site *S7*)						
O_2	4.73	39.3	62	-0.18	20	201
A_1	4.68	22.5	25	<DL	9	30
A_3	4.86	19.6	40	<DL	8	12
Distant-lower slope (Site *S6*)						
O_2	4.75	23.3	165	2	31	238
A_1	4.84	14.9	84	-0.05	9	34
A_3	4.87	2.7	50	<DL	2	4
Near-ridge top (Site *S2*)						
O_2	5.06	38.1	5312	250	316	2113
A_1	5.49	16.4	3361	87	30	105
A_3	5.29	17.0	757	14	24	29
Near-lower slope (Site *S1*)						
O_2	5.86	19.0	4348	68	177	649
A_1	5.69	21.2	4224	69	88	381
A_3	5.11	16.2	632	6	19	10

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[1] ppm per gram dry soil

Figure 3. Total soil bacterial counts in 1975 (Jordan and Lechevalier 1975) *vs*. 2007. Open bars represent distant "control sites" (*S6* and *S7*). Shaded bars represent near "affected sites" (*S1* and *S2*). The top set compares near lower slope vs. distant lower slope sites; the bottom set compares near ridge-top vs. distant ridge-top sites.

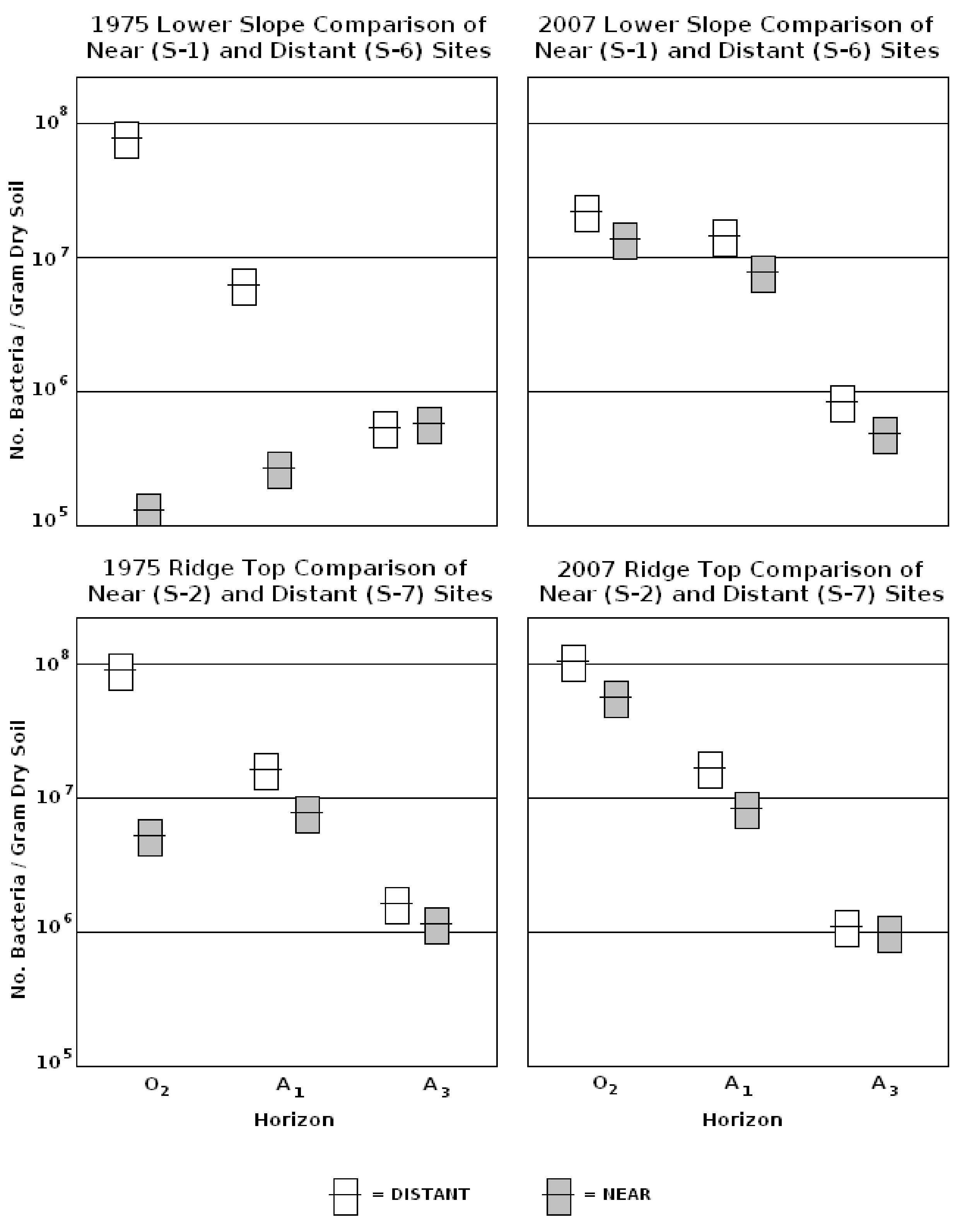
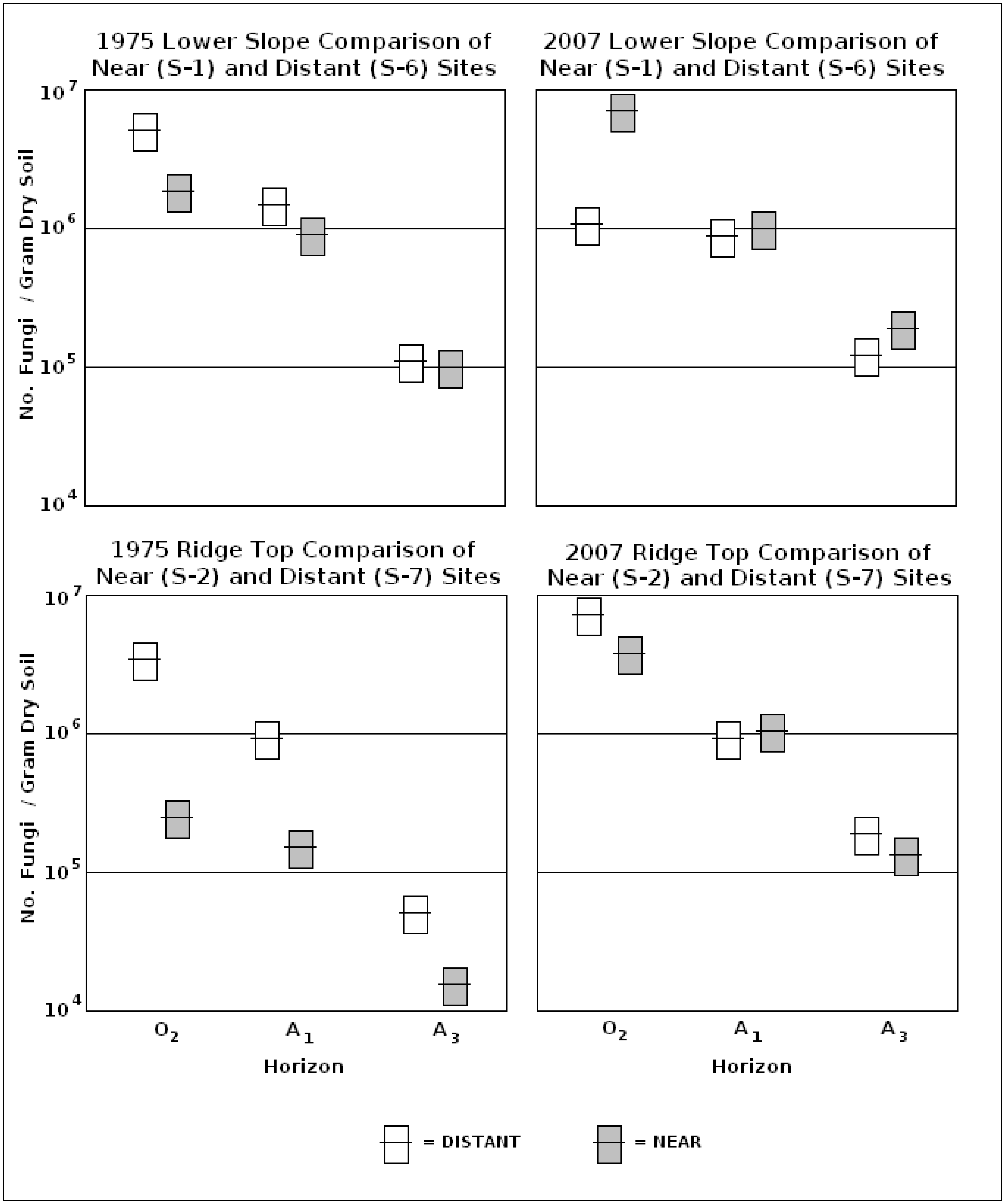


Figure 4. Total soil fungal counts in 1975 (Jordan and Lechevalier 1975) *vs.* 2007 fungal. Open bars represent distant “control sites” (*S6* and *S7*). Shaded bars represent near “affected sites” (*S1* and *S2*). Top set compares near lower slope vs. distant lower slope. Bottom set compares near ridge-top versus distant ridge-top.



1975 Lower Slope Comparison of Near (S-1) and Distant (S-6) Sites

2007 Lower Slope Comparison of Near (S-1) and Distant (S-6) Sites

1975 Ridge Top Comparison of Near (S-2) and Distant (S-7) Sites

2007 Ridge Top Comparison of Near (S-2) and Distant (S-7) Sites

Discussion

The most detrimental characteristic of erosion is the loss of the nutrient rich soil itself. What is left behind is predominately a less active sub-horizon of coarse soil and rock fragments. The remaining soil additionally becomes hampered in its ability to retain water and exchange cations, as well as its capacity to support microbial activity (Brady 1999). At Lehigh Gap near Palmerton, PA, the effects rendered by the process of zinc smelting and the after effects of acid rain, heavy metal deposition, and severe soil erosion has stripped much of the land of its vegetation, leaving behind acres of bare rock. Early stages of soil formation, such as transformation and translocation, are evidenced by the very thin, immature layer (< 5cm) of topsoil at the ridge-top site (*S2*) that overlooks the former smelter. While it is difficult to identify this as a typical O horizon, the A horizon is readily identifiable and immediately under the surface soil. The O horizon contains some organic matter but is largely devoid of any leaf litter. A more prominent O horizon develops as progress is made east-northeast along the Appalachian Trail (Sites *S3*-*S7*).

Heavy metal concentrations have dramatically decreased over the past 32 years since measured by Jordan and Lechevalier (1975), although they still remain significantly higher than what were and are still found in soils located over 40 km from the Palmerton area. 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. The greatest example of microflora recovery was observed from soil samples obtained at *S1* which was reported as being the most heavily contaminated site by Jordan and Lechevalier in 1975. In general, the O horizon has experienced the most dramatic progress.

The environmental impact of heavy metal contaminants strongly depends on the metals' mobilites and bioavailability in soil (Brady, 1999). Although the toxic effect of heavy metals on soil microorganism activity is well known, little is known about the effects on different organism groups. The isolation of *Alcaligenes eutrophus,* a gram-negative bacterium shown to exhibit plasmid-bound resistance to cadmium and zinc (Mergeay, 1985) from these soils may indicate that a microfloral community that is more resistant to heavy metal toxicity may have established itself at these sites.

Acknowledgements

Many thanks are due to Dr. Marilyn J. Jordan, of the Nature Conservancy, Long Island, NY for her assistance in relocating the sample sites that she used in her 1975 study, Mr. Dan Kunkle of the Lehigh Gap Nature Center for providing literature and field assistance, and Drs. Diane Husic and Shari Dunham of Moravian College for their advice. Special thanks go to Mr. Brian Birchak, for his untiring assistance in field sampling during this project. Funding support for this project came from the Moravian College Ervin J. Rokke Endowment for Student-Faculty Research.

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Appendix E-2

EVIDENCE FOR ZINC TOLERANCE AMONG BACTERIA OF THE PALMERTON, PA AREA

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Introduction

The northern face of the Blue Mountain (Kittatinny Ridge) experienced over 1,000 acres of deforestation due to emissions from zinc (Zn) smelters that were operational from 1898-1980 near Palmerton, PA (Beyer 1988). Jordan and Lechevalier (1975) conducted an extensive study that examined the effects of the smelters on soil microorganism populations at seven downwind sites along the Appalachian Trail, from the Lehigh Gap to the Delaware Water Gap.

In 2007, Villafañe and Kuserk (personal communication) conducted a follow up study at the same locations to determine if there had been changes in the soil bacteria numbers and heavy metal levels over the course of more than 30 years. They found that heavy metal concentrations (Zn, Cd, Pb, Cu) in soils closest to the smelters, while still high, had decreased significantly while bacterial numbers had increased.

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.

Methods

Seven sites along Appalachian Trail on the Blue Mountain from the Lehigh Gap to the Delaware Water Gap were originally selected for sampling by Jordan and Lechevalier (1975) and re-located by Villafañe and Kuserk (personal communication) in their recent study (Figure 1). A site close to the smelter (Site 2), a control site far from the smelter (Site 6 = FG) and a site in between (Site 4) were chosen for this study done during the Summer 2008.

Four pits were excavated at each site using a square point shovel. Each pit measured approximately 0.5 m × 0.5 m, and varied in depths of up to 35 cm. At each pit, soil samples from the O_2 (partially decomposed leaf litter), A_1 (upper topsoil) and A_3 (lower topsoil/mineral soil transition) horizons were transferred aseptically into Fisherbrand® 50 ml sterile centrifuge tubes. An alcohol-flamed, stainless steel spatula was used to perform the transfers.

Soil from each horizon (O, A_1, A_3) from two of the four pits, *P1* and *P3,* at each site were combined together for bacterial enumeration. Soil dilutions were prepared within 24 hours using a pour plate technique (Leboffe and Pierce, 2006). Six plates per dilution, per sample were aseptically prepared using Yeast Dextrose Agar (YDA), with the A_1 samples also prepared on

1000μM and 6000μM Zn amended YDA media and incubated at 23°C. After 6 days of incubation, bacterial colonies were enumerated. Soil moisture analysis was performed by

weighig soil samples from the remaining two pits (P2 and P4) before and after air-drying for 48 hours.

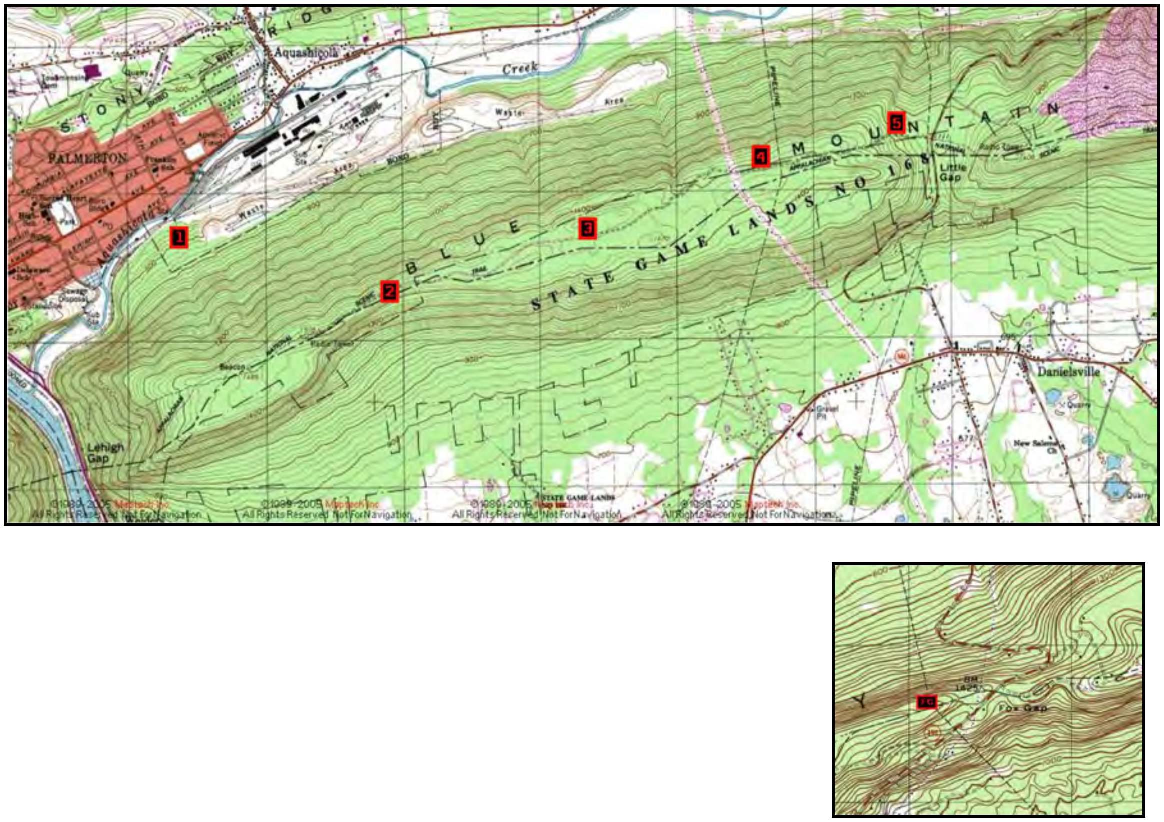


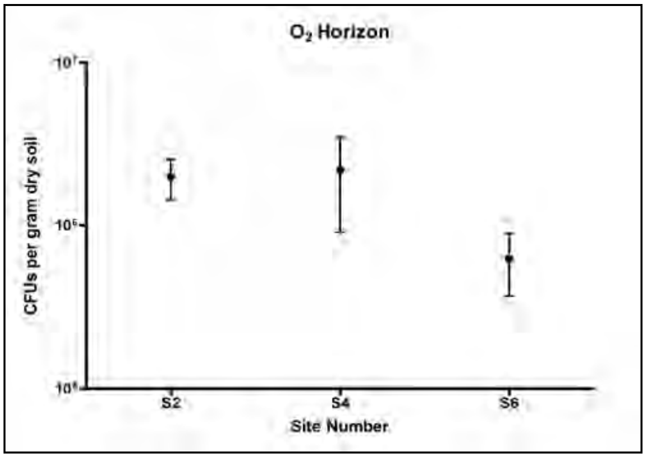
Figure 1. (Top) Map showing the locations of sampling Sites 1-5;

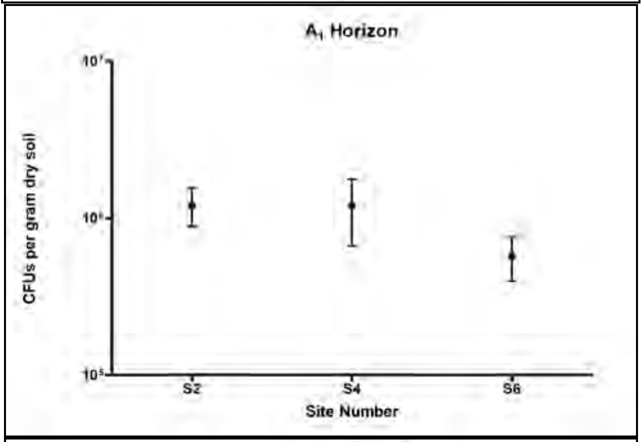
(Bottom) Map showing the location of sampling Site 6 (FG) located east of the main sampling sites at Fox Gap. The FG site is considered the control site because it is located several miles east of the Palmerton, PA sites.

Selected bacterial colonies were isolated and subcultured from enumeration plates from the three sites. Gram stains, spore stains, catalase tests with 3% H_2O_2 and oxidase tests using BBL® DrySlides were also performed when necessary. Colonies were isolated and then sub-cultured on Biolog Universal Growth (BUG™) agar with 5% sheep blood (BUG + B). A 25% sterile solution of maltose and/or thioglycollate was added to analyze for *Bacillus spp.* Bacterial identifications were performed using the Biolog MicroLog ™ Microbial ID/Characterization System (http://www.biolog.com).

Results and Discussion

Figure 2 illustrates the number of colony forming units per gram dry soil enumerated at each sampling site. It can be seen that bacterial levels at the sites closer to the original smelter locations (Sites 2 and 4) have recovered to the levels seen at the control site (Site 6 = FG). This observation supports the results observed by Villafane and Kuserk (personal communication) in their 2007 study.





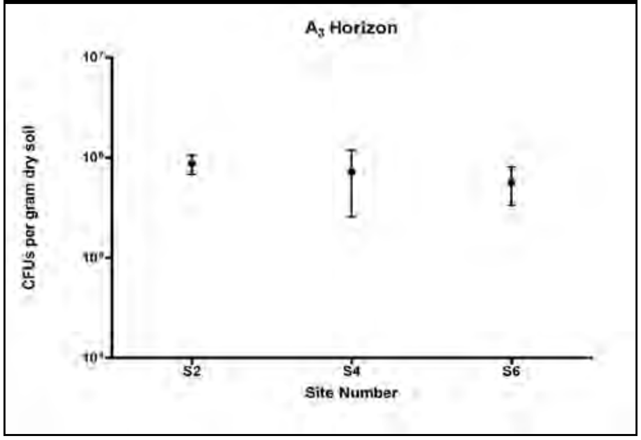


Figure 2. Number of bacterial colony forming units (CFUs) per gram dry soil in the O, A_1, and A_2 horizons at Sites 2, 4 and 6 (FG; control site).

When the soil samples taken from the A_1 horizon at each site were plated onto media amended with zinc, it was found that soil samples collected at sites closer to the original smelters, which have higher zinc levels (Villafañe and Kuserk, personal communication), also had a higher percentage of zinc-tolerant bacterial colonies. Figure 3 shows that bacterial counts on media amended with 1000 µM zinc were 44% and 41% of counts on unammended media at Sites 2 and 4, respectively, whereas it was only 22% when compared to the CFU counts on unammended media at the control site (Site 6 = FG). A smaller variation in zinc tolerance levels between sites can be seen on the 6000 µM Zn amended media. This may be due to the bacteria reaching their upper metabolic limit. These data suggest that the percentage of bacteria isolated from soils closer to the original smelters exhibit higher tolerances to zinc that those isolated from soils located farther from the original smelters. Whether this is due to a microbial community consisting of different, more tolerant species of bacteria at the closer sites or to more zinc-tolerant strains of the same microbial species is not known.

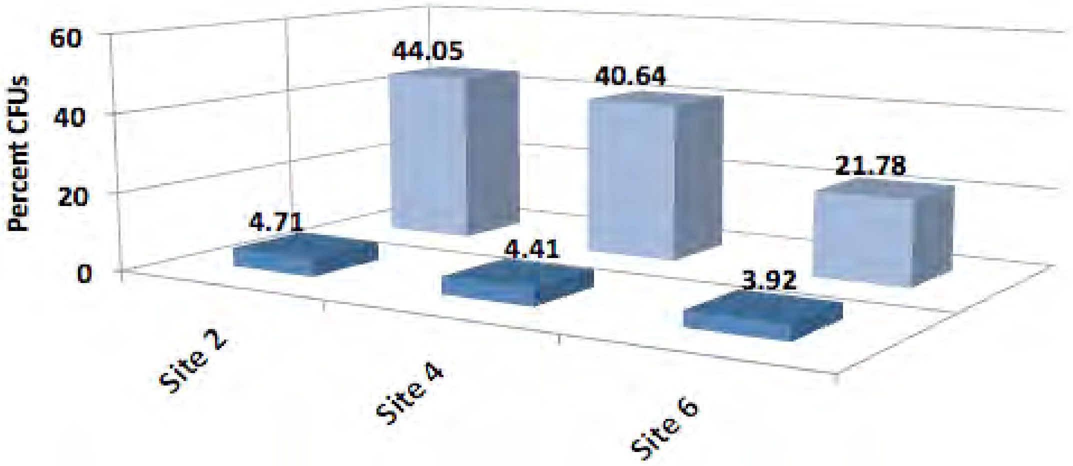


Figure 3. Percentage of soil bacterial colonies from the A1 horizon that were tolerant to 1000 µM zinc (larger bars) and 6000 µM (smaller bars) at Sites 2, 4 and 6 (FG = Control).

Bacteria isolated and identified from soils at all three sites were found to be common soil bacteria, including species from the genera *Staphlococcus*, *Arhtrobacter*, *Psudomonas* and *Rahnella*. 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 would be advised 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 (Garland 1997).

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1742

Evidence for zinc tolerance among bacteria in the Palmerton, PA area

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Abstract

Zinc smelting, which took place in Palmerton, PA for almost a century, denuded a large portion of Blue Mountain's northern slope *(1)*. Studies completed in both 1975 and 2007 showed a decrease in heavy metal contamination along with an increase in bacterial levels to nearly those of control sites *(2, 3)*. This study confirms the rebounding of bacterial levels along with analysis of zinc tolerance among the bacterial populations sampled. Samples taken from sites experiencing higher contamination exhibited higher percentages of zinc tolerance.

Introduction

The northern face of Blue Mountain experienced over 1,000 acres of deforestation due to emissions from a zinc (Zn) smelter located in Palmerton, PA which was in operation from 1898-1980 *(1)*.

In 1975, M. Jordan & M. Lechevalier conducted a study examining the effects of the smelter, including heavy metal deposits, on the soil microorganisms. They selected seven sites along the Appalachian Trail on Blue Mountain, spanning from the Lehigh Gap to the Delaware Water Gap *(2)*.

In 2007, A. Villafañe completed a follow up study of the same location to determine if there had been changes in the soil bacteria numbers and heavy metal levels. He concluded that heavy metal concentrations had decreased and microbial numbers had increased *(3)*.

This year, our research repeated some of the 2007 sampling to evaluate bacterial numbers and looked at zinc tolerance levels among the re-sampled sites, along with identification of the isolated bacteria.

Experimental Method

A site close to the smelter (site 2), a control site far from the smelter (site 6) and a site in between (site 4) were chosen to be sampled (**Fig. 1**). Four holes were dug at each site and samples from the O_2, A_1, & A_3 horizons were taken (**Fig. 2**).

Samples were brought back to the lab and processed within 72 hours using a pour plate technique. All samples were plated on Yeast Dextrose Agar, with the A_1 samples also plated on 1000µM and 6000µM Zn amended media (**Fig. 5**).

Bacterial identification was completed using Biolog MicroLog™ Microbial Identification System (**Fig 5**).

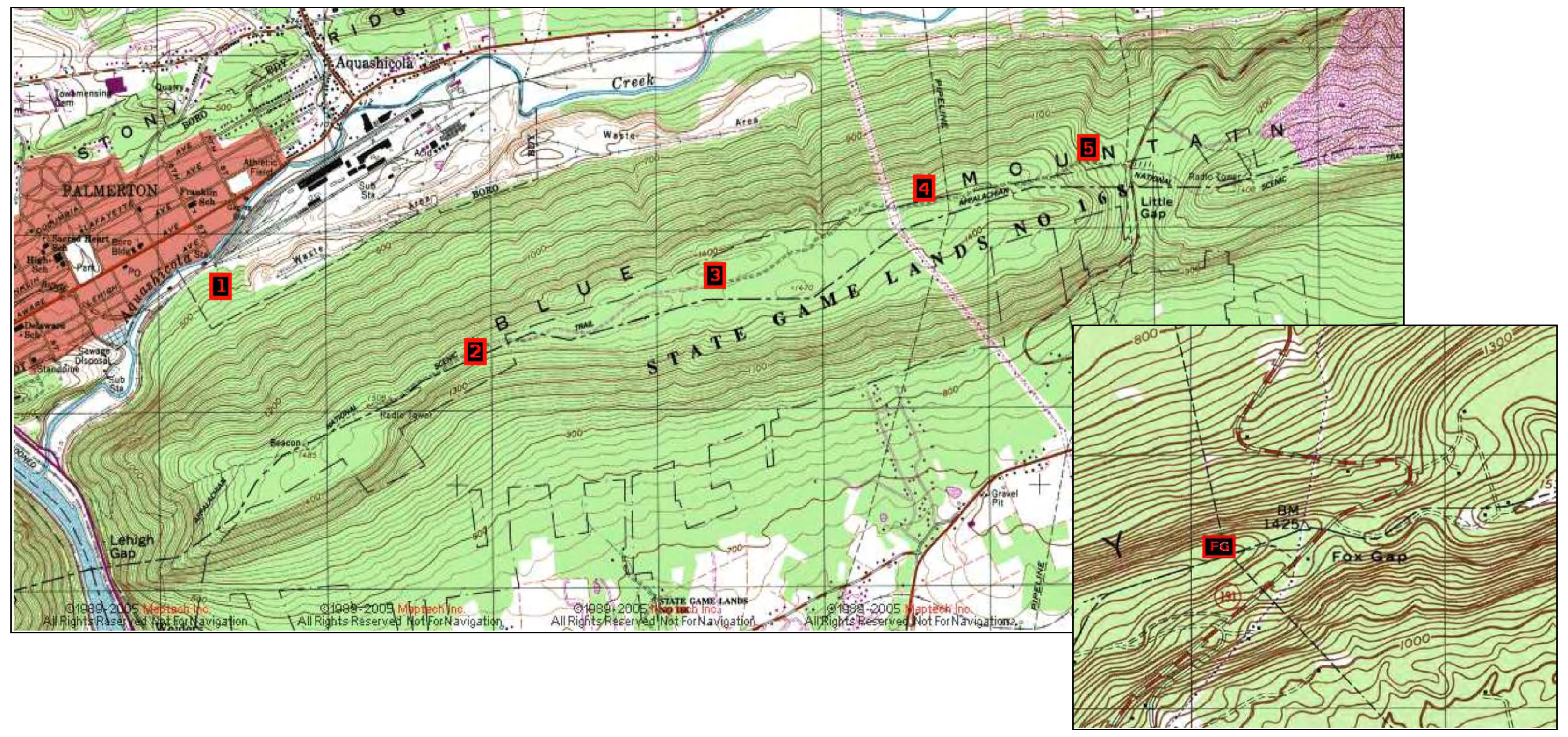

Figure 1. Maps of sampling sites 1-5 and 6 at Fox Gap (FG)

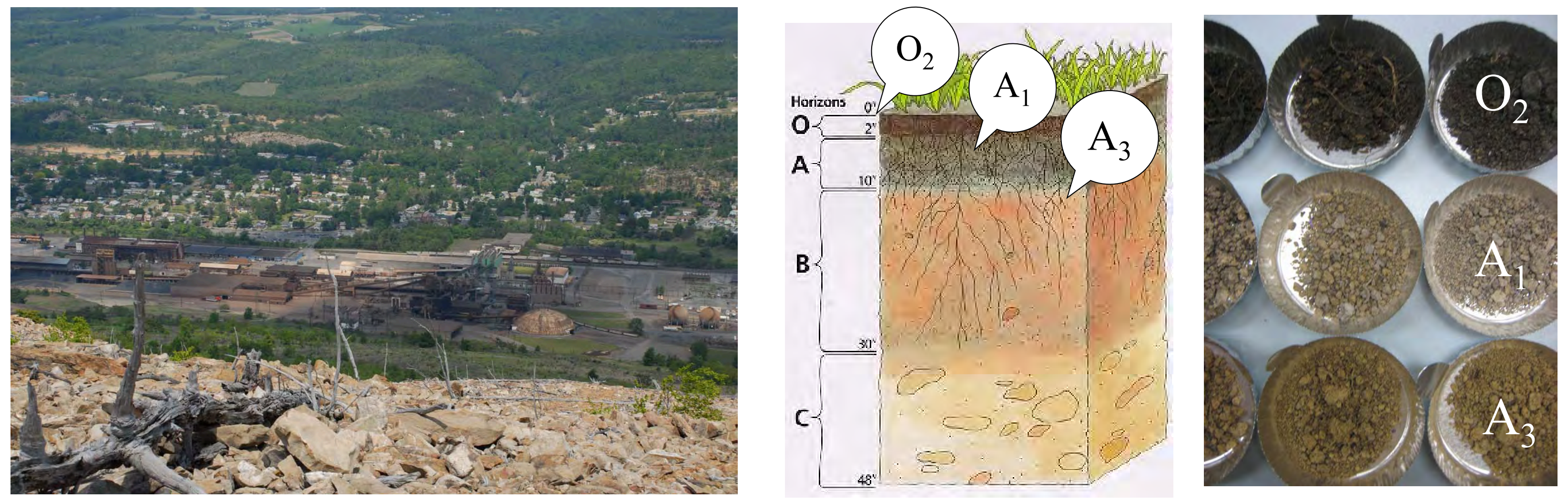

Figure 2. East zinc smelting plant as seen from Blue Mountain (left). Soil profile depicting horizons (center) *(2)*. Soil samples (right)

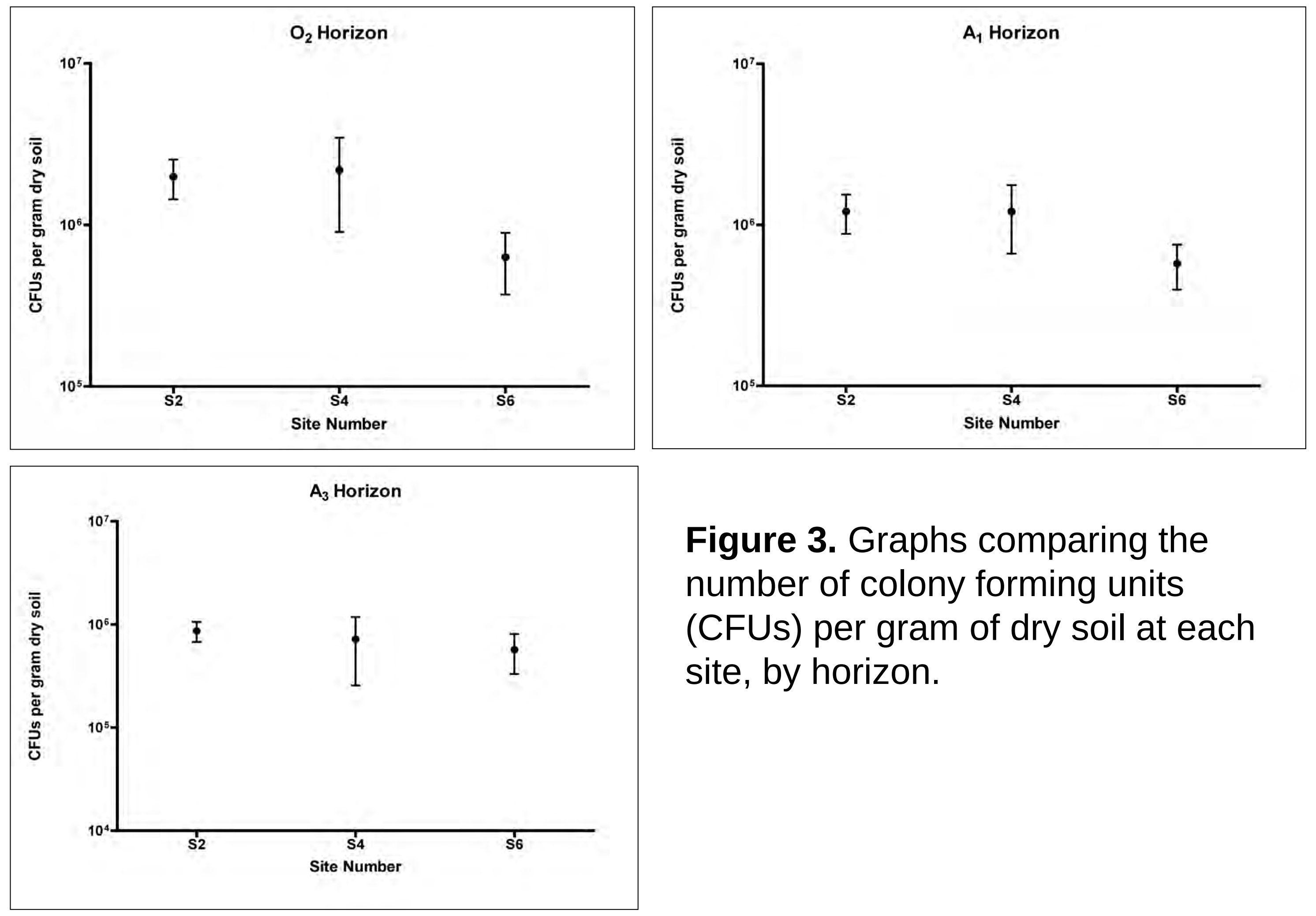

Figure 3. Graphs comparing the number of colony forming units (CFUs) per gram of dry soil at each site, by horizon.

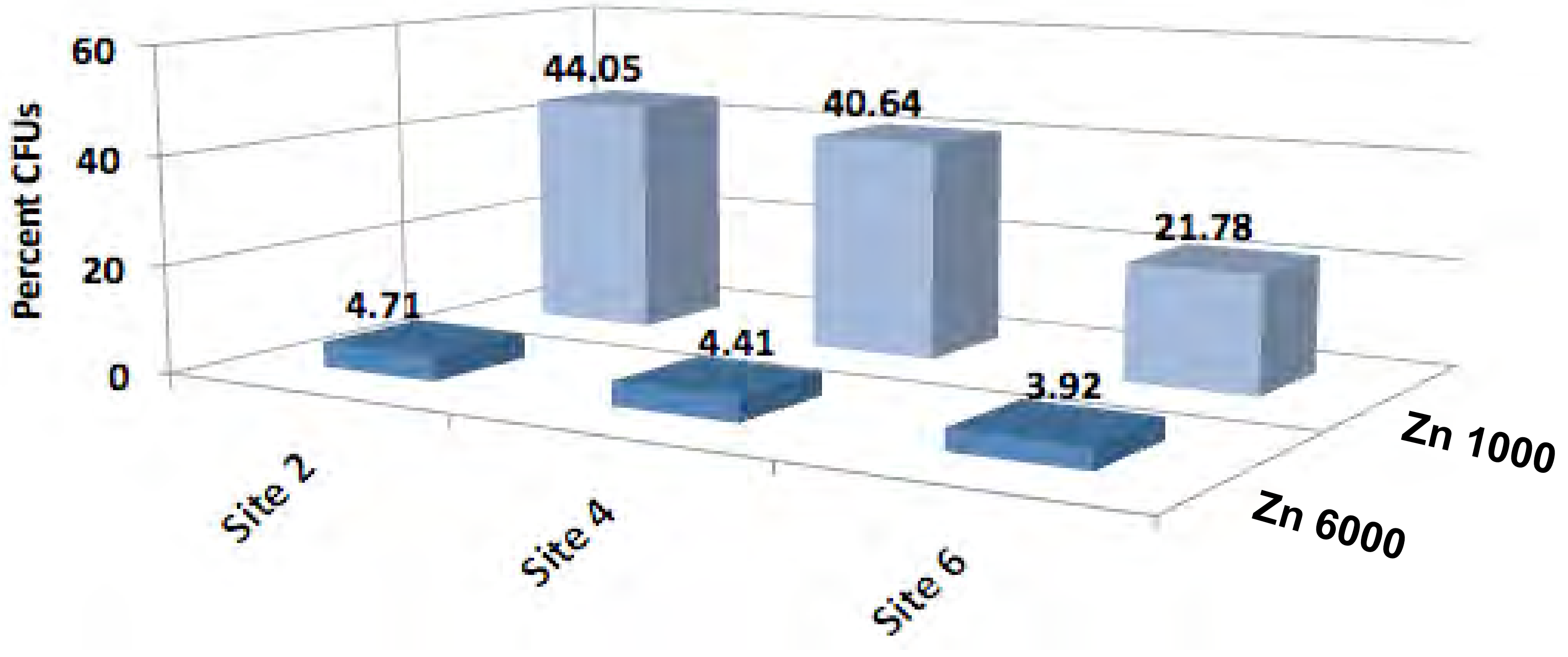

Figure 4. Percentage of zinc tolerant A_1 bacteria at each site on 1000µM & 6000µM zinc amended growth media.

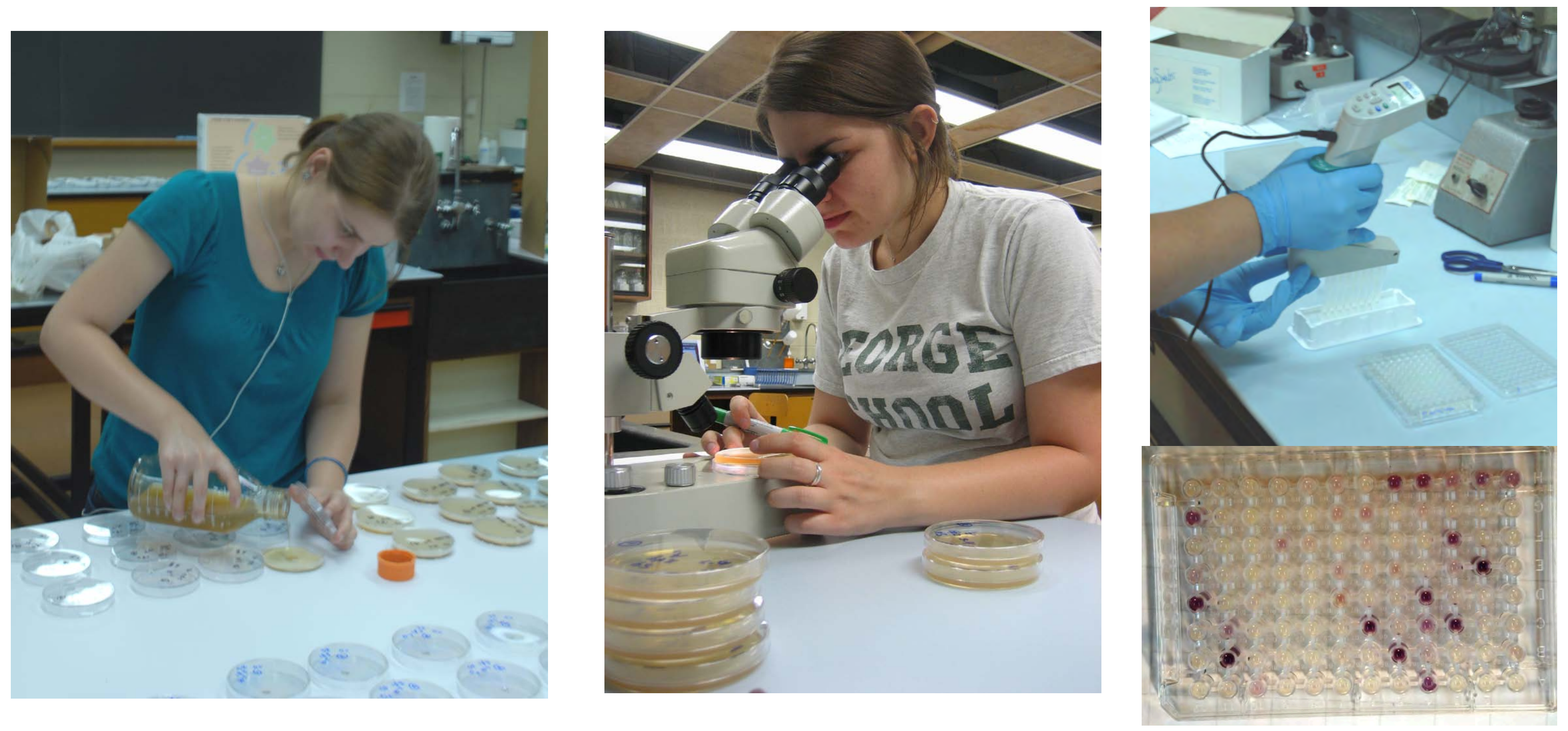

Figure 5. Pour plate technique (left). Plate counting of colony forming units (center). Inoculation and subsequent color change of microplate (right)

Results & Discussion

Figure 3 illustrates the numbers of colony forming units isolated at each site. It can be seen that bacterial levels at the sites close to the smelter location (sites 2 & 4) have recovered to the bacterial levels at the control site (site 6), which is in agreement with last year's data *(3)*.

When the samples of the A_1 horizon were analyzed for zinc tolerance, it was found that as the distance from the smelter decreased, the zinc tolerance exhibited increased. This is depicted in **Figure 4**, which also compares zinc tolerance on two levels of zinc amended media. A smaller variation among tolerance levels between sites can be seen on the 6000µM Zn amended media. This may be due to the bacteria reaching their upper metabolic limit.

Isolated and identified bacteria were found to be common soil bacteria, including the genera *Staphlococcus, Arhtrobacter, Psudomonas* and *Rahnella*. To better evaluate the microbial populations at the sample sites, use of a community-level physiological profiling (CLPP) technique would be advised in place of, or in addition to, the MicroLog™ Microbial Identification System. The CLPP method allows for examination of community metabolism over a week's time, creating a profile of the bacterial community rather than identification of individual members *(4)*.

Acknowledgements

Thanks to Armando Villafañe Jr. for his comments and suggestions and to Andrew Mashintonio for his field assistance. Funding for this project was made possible through the Moravian College Ervin J. Rokke Endowment for Student-Faculty Research.

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APPENDIX E-4

1742

Identification of Bacteria found in Metal Contaminated Soils near Palmerton, PA

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Abstract

Near Palmerton, PA two zinc ore smelters operated by NJ Zinc Co. for 90 years led to the devastation of the surrounding area along the Blue Mountain. For the past two years Moravian College students have performed studies in which they collected samples and 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.

Introduction

From the 1890's until the early 1980's the New Jersey Zinc Company operated two metal smelters near the small town of Palmerton, Pennsylvania. High metal and acidic emissions from these plants led to the devastation of nearly 3,000 acres of forests located on the north slope of Blue Mountain near the Lehigh Gap.

For the past two years studies conducted by Moravian College SOAR students Armando Villafane (Villafane, *et al*. 2007) and Vivian Clarke-Ruiz (Clarke-Ruiz 2008) show that despite continued high metal concentrations in soils near the smelters microbial populations have recovered to levels near those found at more remote areas. In addition, indications are that the microbial communities nearest the smelters may consist of species and/or strains that are more resistant to high zinc levels than communities with lower soil metal concentrations located at more distant sites (Clarke-Ruiz 2008).

In this study I attempted to identify bacteria collected from soil samples at seven different locations along the Appalachian Trail from the Lehigh Gap (nearest the smelters) to the Delaware Water Gap (farthest from the smelters).

Methods

A total of twenty different bacteria samples were collected, isolated, and preserved from soil samples collected by Clarke-Ruiz in her 2008 study. The frozen bacteria were initially transferred to Trypticase soy broth (TSB) in order to revive them. After growth in the broth was evident they were transferred to Trypticase soy agar slants (TSA) and maintained for the duration of the study. Fourteen of the original isolates were successfully revived in this manner. Each isolate was then characterized as to its Gram stain reaction. Further tests for catalase and oxidase production were also performed.

Each of the isolates was grown separately of Biolog® Universal Growth (BUG) Agar plates containing 5% defibrinated sheep blood. The bacteria were then added to tubes of sterile inoculating fluid and the turbidity of the fluid adjusted to Biolog® specifications depending on the properties of the bacteria. 150 µl aliquots of the bacterial suspensions were subsequently pipettted into the 96 wells of either Biolog® GN2 or GP2 plates depending on the isolate's gram-staining reaction. The plates were incubated for 24 hours at 25^{o}C and then visually examined. If the bacteria utilized the different carbon sources in each of the 96 wells after 24 hours the well would change to a purple color. The resultant positive and negative results were then checked against patterns stored in the Biolog® computer databases for matches.

Table 1. Positive Identifications of Bacteria Isolated from Soil Near Zinc Smelters near Palmerton, Pa.

Isolate No.	Identification	% Probability of Biolog® Database Match
4	*Leifsonia aquatica*	100%
5 & 11	*Rahnella aquatilis*	100%
6	*Corynebacterium macginleyi*	99%
9	*Curtobacterium citreum*	97%
18	*Pseudomonas fluorescens* biotype F	89%

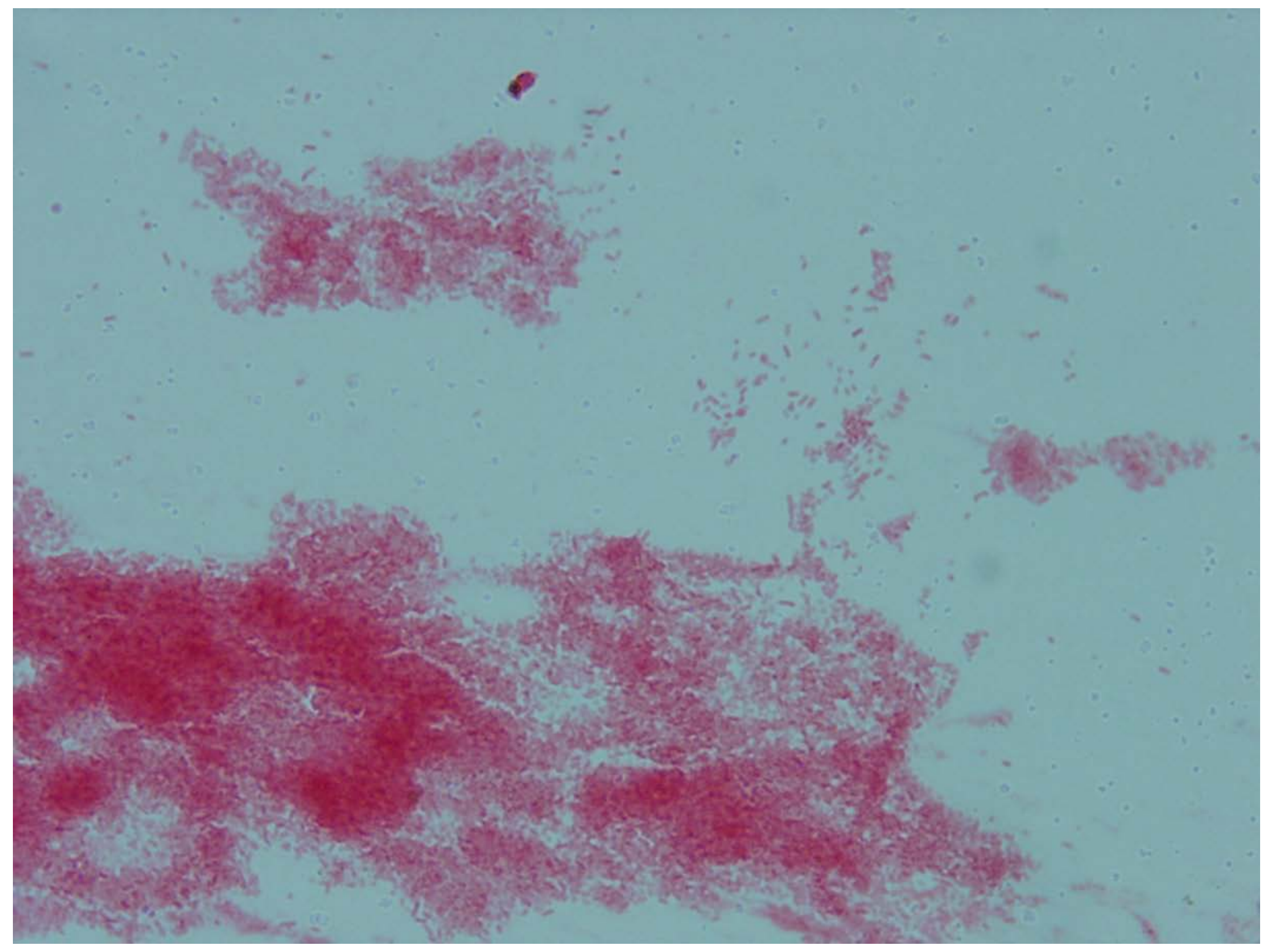

Figure 1. Gram stain of Bacterial Isolate #11 (*Rahnella aquatilis)*

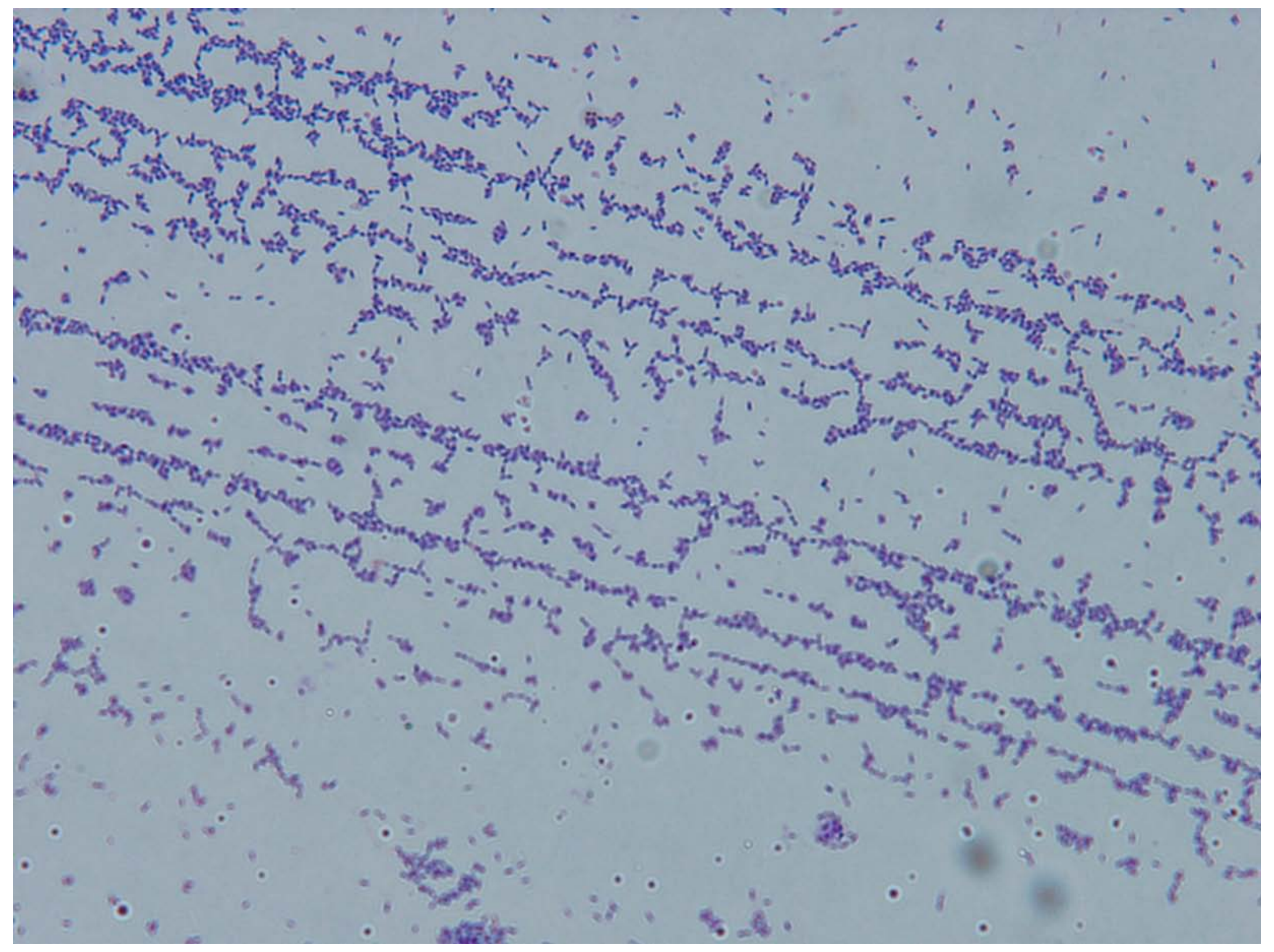

Figure 2. Gram stain of Bacterial Isolate #9 (*Curtobacterium citreum)*

Results and Discussion

Out of the fourteen revived bacteria samples six were positively identified using the Biolog® Microbial Identification System with two samples being the same bacteria (Table 1). These included *Leifsonia aquatic*, *Rahnella aquatilis*, *Corynebacterium*, *Curtobacterium citreum*, and *Pseudomonas fluorescens biotype F*.

For some of the bacterial isolates the inoculating plates were difficult to read and identifications were inconclusive. The wells on some of the plates did not change color at all and on other plates all the wells changed color. Subsequent communications with Biolog® technical support personnel suggest that the isolated strains may either not be in their database or may not match the patterns in their database. Another possibility may be that the isolates may represent entirely new un-identified bacterial species or strains.

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* (Figure 1) is also a gram-negative, rod shaped, nitrogen-fixing, motile bacterial species. It grows best at 30^{o}C and utilizes diverse carbon sources for its growth. It can be found in both water and soil samples.

Corynebacterium is the genus within the broader "coryneform bacteria group" for which the most species have been described to date. *Corynebacterium macginleyi* is a gram-positive, rod-shaped bacteria. This species has also been isolated from conjunctival swabs of patients with either conjunctivitis or corneal ulcers (Funke *et al.* 1998). *Curtobacterium citreum* (Figure 2) is a gram-positive, coryneform soil bacterial species. The optimum growing temperature for this species is 30^{o}C. *Leifsonia aquatica* is a gram- positive, rod shaped, non-motile bacterial species only found 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.

Acknowledgement

We would like to thank the Moravian College Department of Biological Sciences for providing the funds and equipment needed to carry out this project.

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Appendix E-5

Abstract: Casper Laboratory Studies on Arbuscular Mycorrhizal Fungi

A context-dependent party for three: AMF, non-mycorrhizal soil microbes, and plants in a pollution gradient

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Presented at the Ecological Society of America Annual Meeting in August 2010 in Pittsburgh, PA

Investigating how arbuscular mycorrhizal fungi (AMF)-plant interactions vary with edaphic conditions provides an opportunity to test the context-dependency of interspecific interactions, which is currently recognized as a major avenue of future research. We study plant-mycorrhiza symbiotic relationships along a gradient of heavy metal contamination at a recently revegetated "Superfund" site on Blue Mountain, in Palmerton, Pennsylvania. We investigated the interactions involving the native mycorrhizal fungi, non-mycorrhizal soil microbes, soil, and two plant species (a C_3 and C_4 grass) along the contamination gradient.

The native C_3 study species *Deschampsia flexuosa*, is dominant along the gradient and established naturally; the C_4 *Sorghastrum nutans,* is native to Pennsylvania but not to the site and was introduced during restoration. Because C_4 grasses are obligate mycotrophs, we expected *S. nutans* to have a different effect on and response to the soil symbiont community than the C_3 grass. We carried out a full factorial greenhouse experiment using field-collected seeds of *D. flexuosa* and *S. nutans,* soil, AMF spores, and non-mycorrhizal microbes from both high and low contaminated ends of the gradient. After 11 weeks of growth in the greenhouses, we harvested above and belowground plant biomass, and quantified AMF root colonization and AMF sporulation.

Results/Conclusions

Our results indicate that context-dependent function is an important factor driving specific ecological interactions between plants and soil microbes. We found that soil origin significantly affected plant growth. Plants from both species grew much larger in soil from low contaminated (LC) origin than high contaminated (HC) origin. Furthermore, we found that the efficacy of AMF in promoting plant growth depended on AMF origin. Specifically, AMF from LC improved survivorship of *S. nutans* in HC soil compared to AMF from HC.

We also found that the origin of non-mycorrhizal soil microbes affects the benefit provided to plants and likely interacts with AMF in affecting AMF function. Non-mycorrhizal soil microbes from HC origin decreased mean plant size in *D. flexuosa* while microbes from LC origin increased mean plant size compared to plants with no non-mycorrhizal soil microbes added. Our results may be useful for improving our basic ecological understanding of plant-soil interactions and ecotypic variation/context-dependent function. There are also potential applications for restoration of heavy metal polluted sites.

Appendix F-1: Lehigh Gap Wildlife Refuge - Native Habitat Garden Database

Garden	Type of Herb. plant	Common Name	***Scientific Name***	Year
Rock Garden	Grass	Little Bluestem	*Schizachyrium scoparium*	2006
	Grass	Purple Top Grass	*Triden flavus*	2006
	Grass	Prairie Dropseed	*Sporobolus heterolepis*	2006
	Herb. plant	Tickseed	*Coreopsis lanceolata*	2006
	Herb. plant	Sm. Brown-eyed Susan	*Rudbeckia fulgida var.fulgida*	2006
	Herb. plant	Fireworks goldenrod	*Solidago rugosa 'Fireworks'*	2006
	Herb. plant	Stiff goldenrod	*Solidago rigida*	2006
	Herb. plant	Aromatic Aster	*Aster oblongifolius*	2006
	Herb. plant	Wild Bleeding Heart	*Dicentra eximia*	2006
	Herb. plant	Dutchman's Breeches	*Dicentra cucullaria*	2006
	Herb. plant	Bloodroot	*Sanguinaria canadensis*	2006
	Herb. plant	Wild Bergamot	*Monarda fistulosa*	2006
	Herb. plant	Spring Beauty	*Claytonia virginica*	2006
	Herb. plant	Maryland Golden Aster	*Chrysopsis mariana*	2006
	Shrub	Pasture Rose	*Rosa carolina*	2006
	Shrub	Fragrant Sumac	*Rhus aromatica*	2006
	Shrub	American Cranberry Viburnum	*Viburnum trilobum*	2006
	Vine	Coral Honeysuckle	*Lonicera sempervirens*	2006
	Vine	Yellow Honeysuckle	*Lonicera sempervirens 'John Clayton'*	2006
	Herb. plant	Wintergreen	*Gaultheria procumbens*	2006
	Herb. plant	Butterfly milkweed	*Asclepias tuberosa*	2008
	Shrub	Clethra "Ruby Spice"	*Clethra alnifolia*	2008
	Shrub	Grey Owl Juniper	*Juniperis*	2008
	Herb. plant	Pentstemon "Husker's red)"	*Pentstemmon*	2008
	Herb. plant	Nodding onion	*Allium cernuum*	2008
	Herb. plant	Snow flurry aster	*Aster ericoides*	2008
	Herb. plant	Tennessee Coneflower	*Echinacea tennesseensis*	2008
	Herb. plant	Garden Phlox	*Phlox paniculata*	2008
	Herb. plant	Royal catchfly	*Silene regia*	2008
	Herb. plant	Horsetail milkweed	*Asclepias verticillata*	2008
	Herb. plant	Dwarf False Indigo	*Baptisia australis*	2008
	Herb. plant	Pentstemon	*Pentstemon calycosus*	2008
	Herb. plant	Rattlesnake master	*Eryngium yuccafolium*	2008
	Herb. plant	Blue False indigo	*Baptisia australis*	2008
	Herb. plant	Starry campion	*Silene stellata*	2008
	Shrub	Virginia Sweetpire	*Itea virginica*	2008
	Herb. plant	Bluets	*Houstonia caerulea*	2008
	Herb. plant	Blue-eyed Grass	*Sisyrinchium*	2008
Bog Garden	Herb. plant	Swamp milkweed	*Asclepias incarnata*	2006
	Fern	Royal Fern	*Osmunda regalis*	2006
	Fern	Cinnamon Cinnamon	*Osmunda cinnamonea*	2006
	Shrub	Button bush	*Cephalanthus occidentalis*	2006
	Herb. plant	Purple stem aster	*Aster puniceus*	2006
	Herb. plant	Bloodroot	*Sanguinaria canadensis*	2006
	Herb. plant	Cardinal Flower	*Lobelia cardinalis*	2006
	Herb. plant	Marsh Marigold	*Caltha palustris*	2005
	Herb. plant	Trout Lily	*Erythronium americanum*	2006
Pond's Edge	Herb. plant	Iris, slender blue flag	*Iris prismatica*	2006
	Herb. plant	Virginia Bluebells	*Mertensia virginica*	2006
	Herb. plant	Rue Anemone	*Anemonella thalictroides*	2006
	Herb. plant	Iris, Blue Flag	*Iris versicolor*	2006
	Herb. plant	Swamp milkweed	*Asclepias incarnata*	2006

	Shrub	American Hazelnut	*Corylus americana*	2006
	Shrub	High bush blueberry	*Vaccinium corymbosum*	2006
	Shrub	Elderberry	*Sambucus canadensis*	2006
	Shrub	Nine bark	*Physocarpus opulifolius*	2006
Border around Deck	Herb. plant	Tickseed	*Coreopsis lanceolata*	2006
	Herb. plant	Smooth aster	*Aster laevis 'Bluebird'*	2006
	Herb. plant	Maryland Golden Aster	*Chrysopsis mariana*	2006
	Herb. plant	Atlantic Coreopsis	*Coreopsis tripteris*	2006
	Herb. plant	False Sunflower	*Heliopsis helianthoides*	2006
	Herb. plant	Sundrops	*Oenothera fruticosa*	2006
	Herb. plant	Mountain mint	*Pycnanthemum sp.*	2006
	Shrub	Smotth Serviceberry	*Amelanchier laevis*	2006
	Shrub	Summersweet	*Clethra alnifolia 'Hummingbird'*	2006
	Shrub	chokeberry, Black	*Aronia melanocarpa*	2006
	Shrub	Winterberry "Red" Holly	*Ilex verticillata 'Winter Red'*	2006
	Shrub	Male winterberry Holly	*Ilex verticillata 'Southern Gentleman'*	2006
	Vine	Coral Honeysuckle	*Lonicera sempervirens*	2006
Spring House	Herb. Plant	Boltonia	*Boltonia asteroides*	2006
	Herb. Plant	Stiff Goldenrod	*Solidag rigida*	2006
	Herb. Plant	Joe pye weed	*Eupatorium maculatum*	2006
Entrance and Exit Gardens along loop driveway				
	Tree	Eastern red cedar	*Juniperus virginiana*	2008
	Tree	White Pine	*Pinus strobus*	2008
	Tree	Virginia pine	*Pinus virginiana*	2008
	Tree	Chestnut Oak	*Quercus prinus*	2008
	Tree	Silver maple	*Acer saccharinum*	2008
	Tree	Serviceberry	*Amelanchier canadensis*	2008
	Tree	River Birch	*Betula nigra*	2008
	Shrub	Nannyberry viburnum	*Viburnum lentago*	2008
	Shrub	Smooth serviceberry	*Amelanchier laevis*	2008
	Shrub	False Indigo	*Amorpha fruticosa*	2008
	Shrub	Shining sumac	*Rhus copallinum*	2008
	Shrub	Sweet fern	*Comptonia peregrina*	2008
	Shrub	Silky dogwood	*Cornus amomum*	2008
	Shrub	Winterberry	*Ilex verticulata*	2008
	Shrub	Bayberry	*Myrica pennsylvanicum*	2008
	Herb. plant	Swamp milkweed	*Asclepius incarnata*	2008
	Herb. plant	Butterfly milkweed	*Asclepius tuberosa*	2008
	Herb. plant	Horsetail milkweed	*Asclepius verticillata*	2008
	Herb. plant	Aromatic aster	*Aster*	2008
	Herb. plant	Smooth aster	*Aster laevis*	2008
	Herb. plant	New England aster	*Aster novi-anglia*	2008
	Herb. plant	New York aster	*Aster novi-belgii*	2008
	Herb. plant	Boltonia	*Boltonia asteroides*	2008
	Herb. plant	Turtlehead	*Chelone glabra*	2008
	Herb. plant	Joe-pye weed	*Eupatorium fistulosum*	2008
	Herb. plant	Sunflower	*Heliantha strumosus*	2008
	Herb. plant	Bee balm	*Monarda fistulosum*	2008
	Herb. plant	Beardtongue	Pentstemon digitalis	2008
	Herb. plant	Golden groundsel	*Senacio aureus*	2008
	Herb. plant	Stiff goldenrod	*Solidago rigida*	2008
	Herb. plant	Firewowrks goldenrod	*Solidag rugosa*	2008
	Herb. plant	Ironweed	*Veronia novaboracensis*	2008

Prairie Warbler Trail	Herb. plant	Wild Lupine	*Lupinus perennis*	2005
	Shrub	Summersweet	*Clethra alnifolia*	2005
	Shrub	Silky Dogwood	*Cornus amomum*	2005
	Shrub	Elderberry	*Sambucus canadensis*	2005
	Shrub	American Hazelnut	*Corylus americana*	2005
	Shrub	Low bush blueberry	*Vaccinium angustifolium*	2006
	Shrub	Pasture Rose	*Rosa carolina*	2006
	Shrub	American Cranberry Viburnum	*Viburnum trilobum*	2006
	Seeds Herb. planted	Ox-eye sunflower	*Heliopsis helianthoides*	2005
	Seeds Herb. planted	Blazing star	*Liatris spicata (blazing star)*	2005
	Seeds Herb. planted	Partridge Pea	*Chamaecrista fasciculata (partridge pea)*	2005
	Seeds Herb. planted	Wild Senna	*Cassia hebecarpa (wild senna)*	2005
	Herb. plant	Ox-eye (False) Sunflower	*Heliopsis helianthoides*	2009
	Herb. plant	Tall Tickseed	*Coreopsis tripteris*	2009
	Shrub	Virginia Rose	*Rosa virginiana*	2009
	Herb. plant	Woodland Sunflower	*Helianthus divaricatus*	2009
	Herb. plant	Tennessee Coneflower	*Echinacea tennesseensis*	2009
	Shrub	Prickly Pear Cactus	*Opuntia cactaceae*	2009
	Herb. plant	Giant Coneflower	*Rudbeckia maxima*	2009
	Herb. plant	Butterfly Weed	*Asclepias tuberosa*	2009
	Herb. plant	New York Aster	*Aster novi-belgii*	2009
	Shrub	Strawberry Bush	*Euonymus amaricana*	2009
	Shrub	Pinxter Azalea	*Rhododendron periclymenoides*	2009
	Shrub	Summersweet	*Clethra alnifolia*	2009
	Herb. plant	False Indigo	*Baptisia australis*	2009
	Shrub	Highbush Blueberry	*Vaccinium corymbosum*	2009
	Shrub	Gooseberry	*Ribes rotundifolium*	2009
	Herb. plant	Blue mist flower	*Eupatorium coelestinum*	2009
	Vine	Trumpet honeysuckle	*Lonicera sempervirens*	2009
	Herb. plant	Eastern Columbine	*Aquilegia canadensis*	2009
Grassland Test Plots	Seeds Herb. planted	American Chestnut	*Castanea dentata*	2006-07
	Seeds Herb. planted	Partridge Pea	*Chamaecrista fasciculata*	2006
	Seeds Herb. planted	Wild Senna	*Senna hebecarpa*	2006
	Seeds Herb. planted	Wild Lupine	*Lupinus perennis*	2006
	Seeds Herb. planted	Round-head Lespedeza	*Lespedeza capitata*	2006
	Seeds Herb. planted	Butterfly Milkweed	*Asclepias tuberosa*	2006-07
	Seeds Herb. planted	Common Milkweed	*Asclepias syriaca*	2006-07
	Seeds Herb. planted	Ox eye Sunflower	*Heliopsis helianthoides*	2006
	Seeds Herb. planted	Black-eyed Susan	*Rudbeckia hirta*	2006
	Seeds Herb. planted	Brown-eyed Susan	*Rudbeckia triloba*	2006
	Seeds Herb. planted	Smooth Blue Aster	*Aster laevis = Symphotrichum laevis*	2006
	Seeds Herb. planted	Dense Blazing Star	*Liatris spicata*	2006
	Seeds Herb. planted	Blue wild indigo	*Baptisia australis*	2007
	Seeds Herb. planted	White wild indigo	*Baptisia leucantha*	2007
	Seeds Herb. planted	Cream wild indigo	*Baptisia leucophaea*	2007
	Seedlings	Bur (scrub oak)	*Quercus macrocarpa*	2007
Oak Test Area/Bobolink	Seedlings/Acorns	White oak	*Quercus alba*	2007
	Seedlings/Acorns	Chestnut oak	*Quercus montana*	2007
	Seedlings/Acorns	Black oak	*Quercus velutina*	2007
	Seedlings/Acorns	Northern Red oak	*Quercus rubra*	2007
	Seedlings/Acorns	Bur oak	*Quercus macrocarpa*	2007
	Seedlings/Acorns	Post oak	*Quercus stellata*	2007
	Seedlings/Acorns	Blackjack oak	*Quercus marilandica*	2007

New Gardens			**Common Name**	**Botanic Name**	
	ferns				
		f	Fern: Lady	*Athyrium felix-femina*	2010
		f	Goldies Wood Fern	*Dryopteris goldiana*	2010
	grasses/sedges				
		g	Big Bluestem	*Andropogon gerardii*	2010
		g	Sideoats Gramma	*Bouteloua curtipendula*	2010
		g	Blue Wood Sedge	*Carex flaccosperma*	2010
		g	Pennsylvania Sedge	*Carex pennsylvanica*	2010
		g	Bottlebrush Grass	*Elymus hystrix*	2010
		g	Switch Grass	*Panicum virgatum*	2010
		g	Little Bluestem	*Schizachyrium scoparium*	2010
		g	Indian Grass	*Sorghastrum nutans*	2010
		g	Prairie Dropseed	*Sporobolus heterolepis*	2010
	perennial				
		p	Purple Giant Hyssop	*Agastache scrophulariifolia*	2010
		p	Nodding onion	*Allium cernuum*	2010
		p	Plaintain Leaved Pussy Toe	*Antennaria Herb. plantaginifolia*	2010
		p	Goat's-beard	*Aruncus dioicus*	2010
		p	Swamp milkweed	*Asclepias incarnata*	2010
		p	Common Milkweed	*Asclepias syriaca*	2010
		p	Butterfly Weed	*Asclepias tuberosa*	2010
		p	Whorled Milkweed	*Asclepias verticillata*	2010
		p	Blue Wood Aster	*Aster cordifolius*	2010
		p	White Wood Aster	*Aster divaricatus*	2010
		p	Smooth Aster	*Aster laevis*	2010
		p	Big Leaf Aster	*Aster macrophyllus*	2010
		p	New England Aster	*Aster novae-angliae*	2010
		p	Aromatic Aster	*Aster oblongifolius*	2010
		p	Doellingeria umbellata	*Aster umbellatus*	2010
		p	False Indigo	*Baptisia australis*	2010
		p	Boltonia	*Boltonia asteroides*	2010
		p	Harebell	*Campanula rotundifolia*	2010
		p	White turtlehead	*Chelone glabra*	2010
		p	Golden Aster	*Chrysopsis villosa*	2010
		p	Black Cohash	*Cimicifuga racemosa*	2010
		p	TIckseed	*Coreopsis lanceolata*	2010
		p	Pink Threadleaf Tickseed	*Coreopsis rosea*	2010
		p	Purple Coneflower	*Echinacea purpurea*	2010
		p	White Coneflower	*Echinacea purpurea 'White Swan'*	2010
		p	Rattlesnake Master	*Eryngium yuccifolium*	2010
		p	Hardy Ageratum	*Eupatorium coelestinum*	2010
		p	Joe Pye Weed	*Eupatorium maculatum*	2010
		p	Wild Strawberry	*Fragaria virginiana*	2010
		p	Gentian, closed	*Gentiana clausa*	2010
		p	Wild geranium	*Geranium maculatum*	2010
		p	Bowman's Root/Fawn's Breath	*Gillenia trifoliata*	2010
		p	False Sunflower	*Heliopsis helianthoides*	2010
		p	Crested iris	*Iris cristata*	2010
		p	Blazing Star	*Liatris spicata*	2010
		p	Cardinal Flower	*Lobelia cardinalis*	2010
		p	Barbara's Buttons	*Marshallia grandiflora*	2010
		p	Wild Bergamot	*Monarda fistulosa*	2010
		p	Phlox	*Phlox maculata 'Natascha'*	2010
		p	Garden Phlox	*Phlox paniculata*	2010

p	Prairie Phlos	*phlox pilosa*	2010
p	Solomon's Seal	*Polygonatum biflorum*	2010
p	Mountain Mint	*Pycnanthemum virginianum*	2010
p	Sm. Brown-eyed Susan	*Rudbeckia fulgida var.fulgida*	2010
p	Great Rudbeckia/ Dumbo ears	*Rudbeckia maxima*	2010
p	Brown-eyed Susan	*Rudbeckia triloba*	2010
p	Fringe Leaved Petunia	*Ruellia humilis*	2010
p	Stonecrop	*Sedum ternatum*	2010
p	Bluestem Goldenrod	*Solidago caesia*	2010
p	Stiff Goldenrod	*Solidago rigida*	2010
p	Fireworks goldenrod	*Solidago rugosa 'Fireworks'*	2010
p	Indian Pinks	*Spigelia marilandica*	2010
p	Widow's Tears	*Tradescantia virginiana*	2010
p	New York Ironweed	*Vernonia noveboracensis*	2010
p	Culver's Root	*Veronicastrum virginicum*	2010
p	Canada White violet	*Viola canadensis*	2010
shrubs			
s	Serviceberry	*Amelanchier canadensis*	2010
s	Indigo Bush	*Amorpha fruiticosa*	2010
s	Chokeberry, Black	*Aronia melanocarpa*	2010
s	Summersweet	*Clethra alnifolia*	2010
s	Dogwood, Red Osier	*Cornus sericea*	2010
s	Bush Honeysuckle	*Diervilla lonicera*	2010
s	Strawberry Bush	*Euonymus americanus*	2010
s	Smooth hydrangea	*Hydrangea arborescens*	2010
s	Winterberry Holly	*Ilex verticillata*	2010
s	Grey Owl Juniper	*Juniperus virginiana 'grey owl'*	2010
s	Sheep-Laurel	*Kalmia angustifolia*	2010
s	Spicebush	*Lindera benzoin*	2010
s	Red Azalea	*Rhododendron prunifolium*	2010
s	Pinkshell Azalea	*Rhododendron vaseyi*	2010
s	Fragrant Sumac	*Rhus aromatica*	2010
s	Pasture Rose	*Rosa carolina*	2010
s	Elderberry	*Sambucus canadensis*	2010
s	Snowberry	*Symphoricarpos albus*	2010
s	Low bush blueberry	*Vaccinium angustifolium*	2010
s	Highbush Blueberry	*Vaccinium corymbosum*	2010
s	Cranberry	*Vaccinium macrocarpon*	2010
	Witherod	*Viburnum cassinoides*	2010
s	Arrowwood Viburnum	*Viburnum dentatum*	2010
s	Blackhaw viburnum	*Viburnum prunifolium*	2010
s	Highbush Cranberry Viburnum	*Viburnum trilobum*	2010
trees			
t	Black Gum	*Nyssa sylvatica*	2010
vines			
v	Coral Honeysuckle	*Lonicera sempervirens*	2010

Appendix F-2

Experimental Design – Grassland Enhancement/Deer Fencing Project

Maria Tranguch, Corey Husic, Dan Kunkle and Meredith Wright

Introduction

Lehigh Gap Nature Center (LGNC) has successfully revegetated the formerly barren slopes of the Kittatinny Ridge at Lehigh Gap. The surface of the land, essentially devoid of life and with no organic soil consisted of rock, gravel, subsoil (mineral soil) and dead woody debris that has failed to decay in more than 50 years. The top 6-10 inches of mineral soil is contaminated with high concentrations of zinc (maximum 36,000 ppm in 2004 samples), cadmium (527 ppm), lead (3345 ppm), and smaller amounts of several other metals.[1] Samples in a reference area had average levels of 33 ppm zinc, 130 ppm lead, and no detectable cadmium.[2]

The site was placed on the National Priorities List for "Superfund (CERCLA) in 1983, being named the Palmerton Zinc Pile Superfund site. There are four separate units in the site, with the nature center property being part of Operable Unit 1 (OU1). The U.S. Environmental Protection Agency (EPA) Record of Decision for OU1[3] has three requirements regarding reclamation of the site:

1) The site must be revegetated with native plants.
2) Erosion of soil and accompanying metal contamination must be halted.
3) Metals must be sequestered in the soil and not mobilized into the food chain. (Since the site consists of thousands of steep, rocky acres, it is impractical to remove the contaminated soil or plant and later harvest species that accumulate metals to remove them from the site.)

Twenty years after original listing as a Superfund site, a successful remedy had not yet been implemented. In 2003, LGNC (then known as Wildlife Information Center) developed and proposed a remediation plan that was accepted by the responsible party, CBS Operations (formerly Viacom International), and was approved by U.S. EPA.[4] The plan involved planting native prairie grasses, most of them C-4, warm season species. Two of these species, not native to Pennsylvania, but native to the U.S., were planted as bridge species to help with early establishment and erosion control and are diminishing as the other species are increasing in abundance. Two species are cool season, C-3 native grass.

A collaborative effort ensued to implement the plan to use grasses for remediation. Frank and West Environmental Engineers (retained by CBS) worked with LGNC staff and advisors John Dickerson and Bill Mineo to develop planting methods using compost, lime,

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[1] BBL. 2004. Soil and Warm-season Grass Sampling. Prepared for Viacom International and EPA.

[2] Palmerton NRDA Team Report. 2008. 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.

[3] Cercla reference

fertilizer, and grass seed in a mix applied by tractor and manure spreader. On steeper slopes, crop-duster aircraft distributed a mix of fertilizer, lime and seed.[4]

The reclamation effort was successful,[5] resulting in a mountainside blanketed by a mix of native grasses. One of the bridge species (sand lovegrass) remains prominent as of 2008 but is diminishing. In succession plot studies in August 2008, dominant species in various plots included sand lovegrass, big bluestem, indiangrass, switchgrass, Eastern gammagrass, and Canada wild-rye.

Table 1. Grasses used in revegetation of LGNC

Common name	Scientific name	Native to PA	C-3 or C-4
Big bluestem, Niagara	*Andropogon gerardii*	Yes	C-4
Little bluestem, Aldus	*Schizachyrium scoparium*	Yes	C-4
Indiangrass, Holt	*Sorghastrum nutans*	Yes	C-4
Eastern gammagrass	*Tripsacum dactyloides*	Yes	C-4
Switchgrass, Shelter	*Panicum virgatum*	Yes	C-4
Sand lovegrass	*Eragrostis trichodes*	No	C-4
Sand bluestem[a]	*Andropogon hallii*	No	C-4
Atlantic coastal panicgrass	*Panicum amarum*	Yes	C-4
Canada Wild Rye	*Elymus canadensis*	Yes	C-3
Broomsedge[b]	*Andropogon virginicus*	Yes	C-4
Deertongue[b]	*Dichanthelium clandestinum*	Yes	C-3
Purpletop[b]	*Tridens flavus*	Yes	C-4

[a] Deleted from 2006 full-scale planting because of lack of performance in test plots.

[b] Added to 2006 full-scale planting.

The goals of the ROD are being met – native species, erosion halted, and metals accumulated at low levels deemed safe for wildlife and human receptors.[6] A biotic community is developing that includes a suite of decomposers, mycorrhizal fungi, and a host of consumers from insects and small mammals to songbirds and predators. The plant community is also diversifying with forbs such as goldenrods (*Solidago* sp.), 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. In general, the diversity of the plant community is still low.

LGNC now seeks to increase that diversity 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 will not only increase the diversity of other species, but also provide more long-term stability to the ecosystem. Invasive species removal will continue

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[4] Frank and West Environmental Engineers. 2006. Palmerton Zinc Pile Site OU1 Blue Mountain Preliminary Remedial Action Design prepared for CBS Operations and EPA.

[5] Kim, Lena. 2009. A Mountain of Hope. Mid-Atlantic Brownfields and Land Revitalization, U.S. EPA web site. http://www.epa.gov/reg3hwmd/bf-lr/newsletter/2009-Spring/lgnc3.html.

[6] BBL, Inc. 2005. Preliminary Human Health and Ecological Risk Evaluation and Data Summary Report – Warm Season Grass Remediation Area.

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.

Hypothesis

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.

We believe that some forb species will be adversely affected and not survive the stressful physical conditions of the site. Others will be impacted by browsing, especially by deer. Since we do not know which species will be affected by these factors, and since it is costly to introduce these plants, we have designed and implemented a controlled experimental planting of a variety of forbs to monitor their success. The results will allow us 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 us with easily located plants for metal uptake studies in the future.

Methods

In order to monitor success of individual species in this habitat enhancement effort in our restored grassland area, we established three replicated pairs of experimental plots into which forbs were introduced. Each plot is a 30x30 m square, with one of each pair of plots enclosed in an eight-foot tall plastic mesh deer exclosure fence, and an adjacent control plot not enclosed in a fence, thus open to deer browsing. Deer fencing is generally taller than the eight feet used in this experimental model, but the rough, boulder covered terrain makes jumping very difficult for the deer, and installing larger fence posts problematic for us.

Through a process involving our consulting ecologists and horticulturists, a group of nine native forbs representing a wide variety of families and readily available for commercial growing was selected. Each species is native to eastern Pennsylvania, is a grassland compatible species, and can be grown from seeds to produce plugs for transplanting to our test plots at a reasonable cost.

Table 2. Forb species to be produced as plugs for test plots.

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

For each of the nine species, 25 individual plugs were planted in each of the three exclosure plot and in each of the three control plot (a total of 150 plants of each species). The locations of the plots were marked with flags and GPS coordinates (Table 3) so that plants can be found during monitoring. The plants are grouped by species in one quadrant of a grid, with nine 10 m x 10 m quadrants in each grid (Fig. 1).

Table 3. GPS coordinates of experimental plots.

Plot	Latitude	Longitude
Exclosure 1	40°47'37.21’N	75°36'19.27'W
Control 1	40°47'37.21’N	75°37'18.88'W
Exclosure 2	40°47'36.43’N	75°37'22.32'W
Control 2	40°47'36.43'N	75°37'21.97'W
Exclosure 3	40°47'34.04’N	75°37'25.45’W
Control 3	40°47'34.04'N	75°37'24.79’W

A	B	C
D	E	F
G	H	I

Fig. 1. A 30 x 30 m test plot divided by a grid into nine 10 x 10 m quadrants

Since one plot, E, is internal to all the other quadrants, it may encounter benefits with regard to deer browsing. Therefore, we planted a different species in plot E for each of the three pairs of test plots. This should help us understand any advantages/disadvantages of a species planted in the central plot.

The plugs were planted randomly within the quadrant, with the quadrant boundaries marked by flags. Rocky conditions made a planting pattern impractical and random occurrence will more closely resemble a natural system. Spaces between clumps of grass were utilized as planting locations to the extent possible. Volunteers, trained by and under the supervision of staff from Edge of the Woods Native Plant Nursery, planted the plugs. Planting bars were used to create holes, Lehigh County municipal compost was used to fill the hole, and then the plugs were inserted, tamped and watered at the time of planting. No further watering or care occurred. Certain species were available for planting in spring 2009 (April 25,26/May 2) and others were ready for late summer 2009 planting (August 29).

Using the microclimate monitoring system being installed, we will also monitor weather data and soil moisture in or near the plots.

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.

Because small mammals such as voles may also be significant browsers on herbaceous vegetation, we also plan to use inked tiles to monitor small mammal presence in the test plot areas in 2010. The monitoring protocol for the mammal printing was developed in conjunction with Rex Lord, PhD (personal communication).

The *monitoring protocol* for the plants is as follows:

1) Plots will be monitored monthly if possible during the growing season. The monitoring will continue for at least two growing seasons (2009-2010), and may continue well beyond this time.
2) For each species, data (see Appendix 1 in this report) is collected as to:
   a. Presence or absence of plant (note if a chewed stem indicates plant lost to browsing, dead plant, or no evidence of plant)
   b. Presence of wilting
   c. Color
   d. Amount and type of herbivory (holes in leaves, leaf margins, between veins, entire leaves, entire plant with stem stub remaining)
3) Digital photographs will be used to document herbivory, with a checkmark or X on the data sheet indicating that a photo was taken.
4) Appendix 1 is the data sheet for monitoring the plots. One sheet is used for each species/quadrant in each plot.

After the first monitoring took place in June, poor survival was noted for *Eupatorium dubium, Asclepias tuberosa,* and *Monarda fistulosa*. We believe that intense heart and dry conditions, which occurred in late April immediately after the plants were installed, caused the mortality. Since the numbers of these plants had dropped below a threshold for valid statistical analysis, we added more plants. We added 25 *E. dubium*, 25 *A. tuberosa*, and 35 *M. fistulosa* to replace plants that had died.

Results

As of this writing, three rounds of monitoring have been performed. The first round occurred from 12-18 June. The second round occurred during the week of 6-10 July. The third round occurred on 18-19 August.

For each of six species, 25 plugs were planted in one quadrant of each plot in April/May 2009. Table 4 shows the surviving number of plants found in the June monitoring, with Table 5 showing the July monitoring results and Table 6 showing the August monitoring results.

The survival rate among the species ranged from 44% for *E. dubium* to 87% for *O. fruticosa*, with an average survival rate of 70% for all species. The survival rate inside the exclosures was 67%, while outside was 72%.

Table 4. Survival rate as of 15 June 2009 of six species planted in April/May 2009.

Plot Code	Coreopsis	Rudbeckia	Oenothera	Eupatorium	Monarda	Asclepias	**Total**
C1	21	25	25	0	13	17	101
E1	16	21	21	17	20	11	106
C2	15	25	24	6	21	11	102
E2	21	20	25	3	26	13	108
C3	21	22	22	4	11	12	92
E3	16	8	23	8	10	13	78
Total	**110**	**121**	**140**	**38**	**101**	**77**	**587**
% Survival	**73%**	**81%**	**93%**	**25%**	**67%**	**51%**	**65%**
% Inside	**71%**	**65%**	**92%**	**37%**	**75%**	**49%**	**65%**
% Outside	**76%**	**96%**	**95%**	**13%**	**60%**	**53%**	**66%**

Table 5. Survival rate as of 10 July 2009 of six species planted in April/May 2009. Note that 85 plants (35 Monarda, 25 Eupatorium, 25 Asclepias) were added to the test plots after June monitoring.

Plot Code	Coreopsis	Rudbeckia	Oenothera	Eupatorium	Monarda	Asclepias	**Total**
C1	21	22	23	6	13	18	**103**
E1	14	16	20	15	21	18	**104**
C2	17	24	22	9	19	18	**109**
E2	21	20	25	14	23	16	**119**
C3	22	23	22	12	23	11	**113**
E3	15	11	18	10	15	10	**79**
Total	**110**	**116**	**130**	**66**	**114**	**91**	**627**
% Survival	**73%**	**77%**	**87%**	**44%**	**76%**	**61%**	**70%**
% Inside	**67%**	**63%**	**84%**	**52%**	**79%**	**59%**	**67%**
% Outside	**80%**	**92%**	**89%**	**36%**	**73%**	**63%**	**72%**

Table 6. Survival rate as of 19 August 2009 of six species planted in April/May 2009.

Plot Code	Coreopsis	Rudbeckia	Oenothera	Eupatorium	Monarda	Asclepias	**Total**
C1	22	23	23	13	14	5	100
E1	15	15	21	13	20	18	102
C2	17	18	16	11	21	19	102
E2	19	19	16	13	19	17	103
C3	22	22	20	14	20	8	106
E3	19	10	23	9	17	6	84
Total	**114**	**107**	**119**	**73**	**111**	**73**	**597**
% Survival	**76%**	**71%**	**79%**	**49%**	**74%**	**49%**	**66%**
% Inside	**71%**	**59%**	**80%**	**47%**	**75%**	**55%**	**64%**
% Outside	**81%**	**84%**	**79%**	**51%**	**73%**	**43%**	**68%**

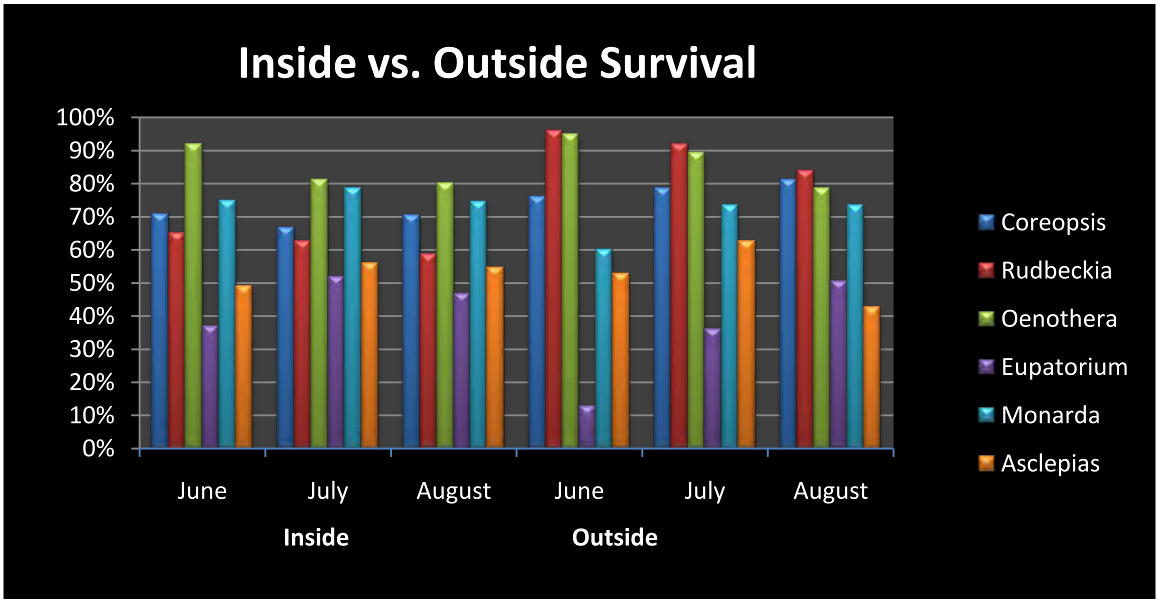
As of August 19, 597 of 900 plants remain (66% survival) with no significant difference between the areas within or outside of exclosures. Survival rates of four species were above 70% (Oenothera, Coreopsis, Monarda, and Rudbeckia), while two were under 50% (Eupatorium and Asclepias). Note that plants added to replace those lost by early drought were counted as original plants in these calculations.

Browsing pressure varied among species with the number of plants showing browsing ranging from 4 to 55% for the six species. (Table 7)

Table 7. Percent of plants browsed per species.

Rudbeckia	55%	Eupatorium	41%
Oenothera	48%	Monarda	12%
Coreopsis	45%	Asclepias	4%

Table 8. Survival rate as of 16 August 2009 of six species planted in April/May 2009, comparing rates inside and outside of deer exclosures.



Discussion

In order that we might avoid loss of plants from hot, dry weather, we planned the spring plantings for the last week of April and first week of May for the six species that were ready for spring planting. (Volunteers will plant the remaining 3 species in late August/early September.)

In spite of our best efforts to avoid hot dry weather in the first weeks after planting, the last week of April had no rain and daily temperatures in the 90sºF. As a result, many young plants died and were absent by the time of the first round of monitoring, with no sign of the plant at all. Numbers of surviving plants of three species (*M. fistulosa, E. dubium,* and *A. tuberosa*) were too low to continue testing their resistance to browsing pressure. Thirty-five *M. fistulosa* and 25 each of *E. dubium* and *A. tuberosa* were added to the plots. This led to an increase in survival rates in July as compared with June, which is counter-intuitive without the added plants. While the weather was inordinately hot and dry just after planting in late April, there was abundant rainfall in June and lower than average heat in July, leading to excellent survival rates in these months.

Table 8 shows little difference in survival within and outside exclosures. In fact, the plants in the control plots (outside the exclosures) fared slightly better than those inside as of 19 August 2009. Up to this point, we can say that with these six species, it appears that the current deer and rodent populations pose little or no threat to their survival. The vast majority of browsing evidence was consistent with browsing by herbivorous insects.

The insect herbivory that was evident on many the plants is considered a good sign. The browsing noted was not enough to kill the plants and we assume that these native plants are hosting native insect species, creating a more diverse habitat and broadening the diversity of producers in the ecosystem. This is one of the goals of introducing these native forbs to the grassland.

Another goal of the grassland enhancement is introduction of flowering forbs that produce nectar and pollen for bees, butterflies, and other native pollinators. Since these forbs are perennials, that flowering was minimal in the first 3 season of growth and much more is expected next year. Flowering occurred in a few of the *Oenothera* and *Coreopsis* plants.

Three species (*Baptisia australis*, *Solidago rigida*, and *Aster laevis*) were planted on August 29, completing the planting in the experimental plots. Monitoring will include those species in 2010. Monitoring continued in 2010 and data is being analyzed. Conclusions will be drawn after this is completed and this will include winter survival information which was not been accounted for in the earlier analysis.

Finally, three experimental 30 m square exclosures were installed on the forested part of the refuge. Two of these plots were heavily covered with Hay-scented Fern. We used herbicide 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 us determine what is inhibiting herbaceous, shrub, and understory vegetation and tree regeneration in these areas. Hypotheses include metal contamination, deer browsing pressure, and the abundance of ferns preventing normal habitat development in these forests.

Appendix 1. Plant monitoring data sheet. Species ____________________________
Test Plot ID# _______ Quadrat ID letter _______ Coordinates ______________________________
Date _______________ Time (EST) ____________________ Temp (ºC) ____________________
Wind sp./dir. ________ % cloud ______________________ Precipitation _________________

Plant#	Present/ Absent	Height (cm)	Color (dk gr, lt gr, ylw, brn)	Turgid/ wilted	Evidence of herbivory (leaf margins, holes, between veins, entire leaf, stem)	Photo X
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						

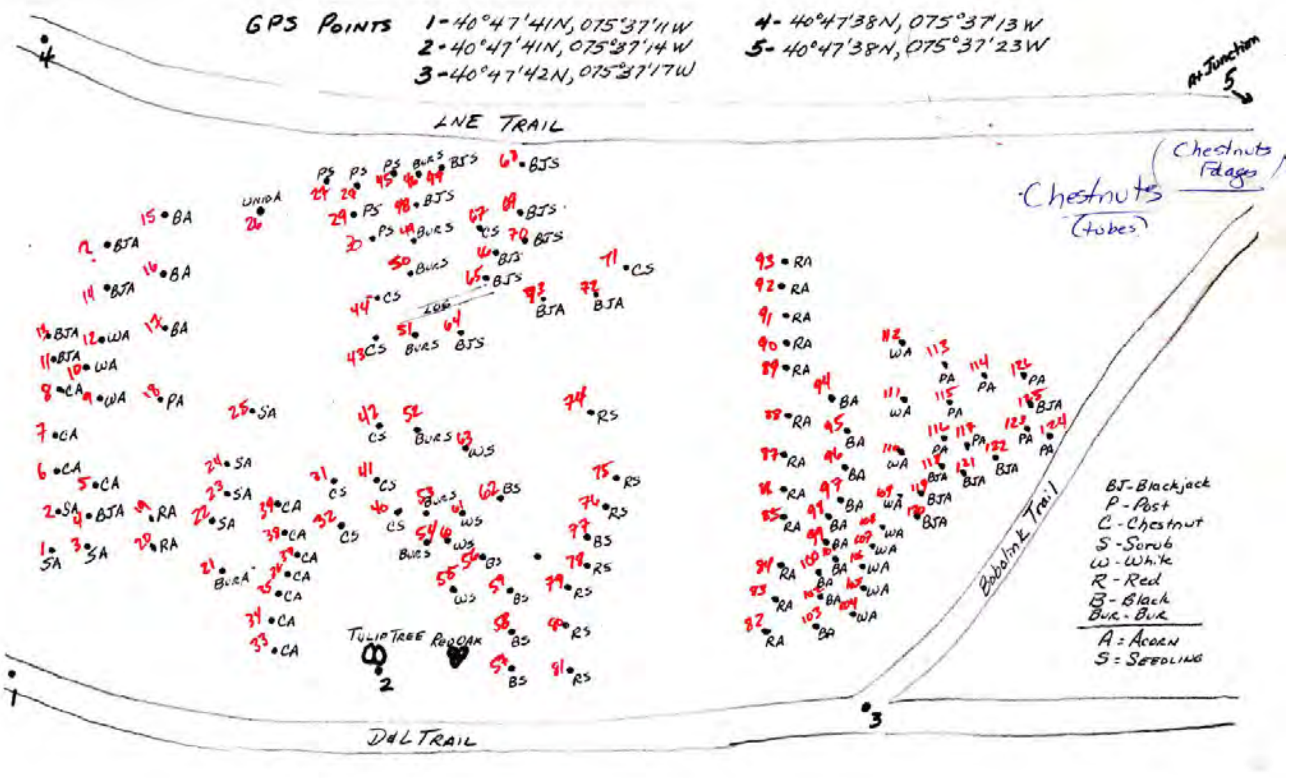
Grassland Enhancement Monitoring
Surviving Test Plants by Plot of 25 Planted

Jun-09	**2009 Plant Monitoring Data - Habitat Enhancement Study**						
Plot Code	Coreopsis	Rudbeckia	Oenothera	Eupatorium	Monarda	Asclepias	**Total**
C1	21	25	25	0	13	17	101
E1	16	21	21	17	20	11	106
C2	15	25	24	6	21	11	102
E2	21	20	25	3	26	13	108
C3	21	22	22	4	11	12	92
E3	16	8	23	8	10	13	78
Total	**110**	**121**	**140**	**38**	**101**	**77**	**587**
% Survival	**73%**	**81%**	**93%**	**25%**	**67%**	**51%**	**65%**
% Inside	**71%**	**65%**	**92%**	**37%**	**75%**	**49%**	**65%**
% Outside	**76%**	**96%**	**95%**	**13%**	**60%**	**53%**	**66%**
Jul-09							
Plot Code	Coreopsis	Rudbeckia	Oenothera	Eupatorium	Monarda	Asclepias	**Total**
C1	21	22	23	6	13	18	103
E1	14	16	20	15	21	16	102
C2	16	24	22	9	19	18	108
E2	21	20	25	14	23	16	119
C3	22	23	22	12	23	11	113
E3	15	11	16	10	15	10	77
Total	**109**	**116**	**128**	**66**	**114**	**89**	**622**
% Survival	**73%**	**77%**	**85%**	**44%**	**76%**	**59%**	**69%**
% Inside	**67%**	**63%**	**81%**	**52%**	**79%**	**56%**	**66%**
% Outside	**79%**	**92%**	**89%**	**36%**	**73%**	**63%**	**72%**
Aug-09							
Plot Code	Coreopsis	Rudbeckia	Oenothera	Eupatorium	Monarda	Asclepias	**Total**
C1	22	23	23	13	14	5	100
E1	15	15	21	13	20	18	102
C2	17	18	16	11	21	19	102
E2	19	19	16	13	19	17	103
C3	22	22	20	14	20	8	106
E3	19	10	23	9	17	6	84
Total	**114**	**107**	**119**	**73**	**111**	**73**	**597**
% Survival	**76%**	**71%**	**79%**	**49%**	**74%**	**49%**	**66%**
% Inside	**71%**	**59%**	**80%**	**47%**	**75%**	**55%**	**64%**
% Outside	**81%**	**84%**	**79%**	**51%**	**73%**	**43%**	**68%**

Appendix F-3

Acorn and Seedling Planting – Field Trials

Map of location of plantings



	Tree			
		5/15/2008		
#'s:	**Acorn/Seed**	**Observation**		
1	SA	NG		
2	SA	NG		**Oak Tree Plotted Points**
3	SA	NG		**Lehigh Water Gap**
4	BJA	NG		**Nature Center**
5	CA	NG		
6	CA	NG		
7	CA	NG		
8	CA	NG		
9	WA	NG		
10	WA	NG		
11	BJA	NG		
12	WA	NG		
13	BJA	NG		
14	BJA	NG		
15	BA	NG		
16	BA	NG		
17	BA	NG		
18	PA	NG I		
19	RA	NG		
20	RA	NG		
21	BURA	NG		
22	SA	NG	*Tree Labels*	
23	SA	NG	BJ	Blackjack
24	SA	NG	P	Post
25	SA	NG	C	Chesnut
26	UNIDA	NG	S	Scrub
27	PS	NG	W	White
28	PS	NG	R	Red
29	PS	G	B	Black
30	PS	G	BUR	BUR
			A	Acorn
31	CA	G+	S	Seedling
32	CA	G+		
33	CA	NG		
34	CA	NG	Observation:	
35	CA	NG		
36	CA	NG	**G**	Growth
37	CA	NG	**NG**	No Growth
38	CA	NG	**I**	Interupted (Erosion)

39	CA	NG	**Y**	Yet to yield leaves
40	CA	G+	**L**	Leaves different than expected
41	CA	G+	**+**	Exceeding average growth
42	CA	G Y		
43	CA	G+		
44	CA	G L		
45	PA	NG		
46	BURS	NG		
47	BJS	G		
48	BJS	G Y		
49	BURS	G Y		
50	BURS	G		
51	BURS	G		
52	BURS	NG		
53	BURS	G Y		
54	BURS	G		
55	WS	G Y		
56	BS	G Y		
57	BS	G Y		
58	BS	G Y		
59	BS	G F		
60	WS	G Y		
61	WS	G F		
62	BS	G F		
63	WS	G Y		
64	BJS	G		
65	BJS	NG		
66	BJS	NG		
67	CS	NG	*Tree Labels*	
68	BJS	G Y	BJ	Blackjack
69	BJS	NG	P	Post
70	BJS	G Y	C	Chesnut
			S	Scrub
71	CS	G+	W	White
72	BJA	NG	R	Red
73	BJA	NG	B	Black
			BUR	BUR
74	RS	G Y	A	Acorn
75	RS	G Y	S	Seedling
76	RS	G Y		
77	RS	G Y		
78	RS	G	Observation:	
79	RS	G+		

80	RS	G Y	**G**	Growth
81	RS	G+	**NG**	No Growth
			I	Interupted (Erosion)
82	RA	NG	**Y**	Yet to yield leaves
83	RA	NG	**L**	Leaves different than expected
84	RA	NG	**+**	Exceeding average growth
85	RA	NG		
86	RA	NG		
87	RA	NG		
89	RA	NG		
90	RA	NG		
91	RA	NG		
92	RA	NG		
93	RA	G		
94	BA	NG		
95	BA	NG		
96	BA	NG		
97	BA	NG		
98	BA	NG		
99	BA	NG		
100	BA	NG		
101	BA	NG		
102	BA	NG		
103	BA	NG		
104	WA	NG		
105	WA	NG		
106	WA	NG		
107	WA	NG		
108	WA	NG		
109	WA	NG		
110	WA	NG		
111	WA	NG		
112	WA	NG	*Tree Labels*	
			BJ	Blackjack
113	PA	NG	P	Post
114	PA	NG	C	Chesnut
115	PA	NG	S	Scrub
116	PA	NG	W	White
117	PA	NG	R	Red
			B	Black
118	BJA	NG	BUR	BUR
119	BJA	NG	A	Acorn
120	BJA	NG	S	Seedling
121	BJA	NG		

122	BJA	NG		
			Observation:	
123	PA	G (minimal)		
124	PA	NG	**G**	Growth
125	BJA	NG	**NG**	No Growth
126	NG	NG	**I**	Interupted (Erosion)
			Y	Yet to yield leaves
			L	Leaves different than expected
			+	Exceeding average growth

APPENDIX G

THE CENTRAL ROLE OF PLANTS IN THE ECOLOGICAL RESTORATION OF A PORTION OF THE PALMERTON SUPERFUND SITE

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ABSTRACT

The Lehigh Gap Wildlife Refuge is a 750-acre tract on the Kittatinny Ridge bordered by the Lehigh River, Appalachian Trail, and Delaware and Lehigh National Heritage Corridor. It is also part of the Palmerton Zinc Pile Superfund site.[1] Eighty years of zinc smelter air pollution (SO_2 and metal particulates) resulted in a landscape almost devoid of vegetation. Beginning in 2003, metal-tolerant warm season grasses were tested as a means to revegetate the steep terrain, stop both the severe erosion and redistribution of the toxic metals, and serve as the first step in habitat restoration. The addition of soil amendments that accompanied the grass seeding apparently provided conditions sufficient for the emergence of both pioneering and invasive plant species. Certain saplings such as grey birch take up zinc and show extreme signs of stress. In contrast, the PA-endangered native species wild bleeding heart and a rare, non-native species, sandwort, are thriving, despite accumulating high levels of zinc. Monitoring the sandwort population size and distribution may help determine if this plant is an indicator of heavy metal bioavailability. Such studies provide the baseline for ongoing succession and biodiversity studies at the restoration site.

INTRODUCTION

The Palmerton Zinc Pile Superfund site resulted from decades of zinc smelter operations. Between 1918 and 1962, sulfur dioxide (SO_2) emission rates were estimated to be between 3,300 and 3,600 pounds per hour.[2] Extraordinary levels of heavy metals were also emitted including zinc (3,575 tons/yr), lead (95 tons/yr), cadmium (47 tons/yr) and others.[2] Zinc levels in the remaining mineral soil at the lower part of the slopes were as high as 80,000 ppm.[3] This pollution resulted in a landscape essentially devoid of vegetation (see Fig. 1a & b), serious erosion problems, and spread of the toxic metals into the Lehigh River. In 2002, a group of local citizens purchased a 750 acre tract on the Kittatinny Ridge within the Superfund site with the goal of reestablishing a thriving habitat on the property and creating what has become known as the Lehigh Gap Nature Center (LGNC).

Beginning in 2003, metal-tolerant warm season grasses were tested as a means to revegetate the steep terrain, stop both the severe erosion and redistribution of the toxic metals, and serve as the first step in habitat restoration.[1,4,5] As can be seen in Fig. 1 c & d, these preliminary tests and subsequent wide-spread seeding have led to the establishment of not only vegetative cover on the once denuded mountainside, but also the creation of a grassland habitat which once again has an array of wildlife including breeding birds, insects, reptiles, and small mammals.

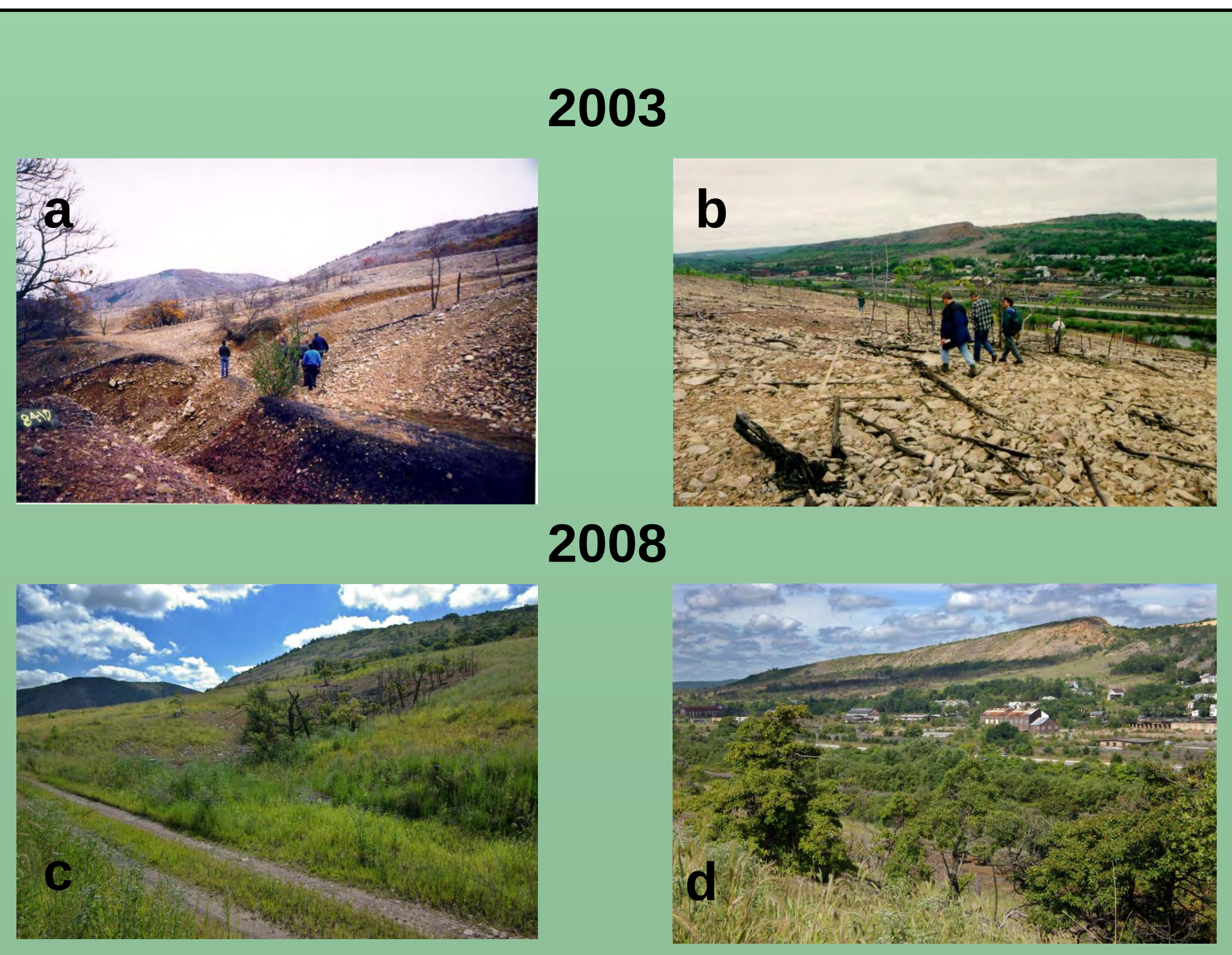

Figure 1. Scenes from the LGNC before (a & b) and after (c & d) restoration plantings of warm season grasses.

The addition of soil amendments (compost and lime) that accompanied the grass seeding apparently provided conditions sufficient for the emergence of some pioneering species, as well as a number of aggressive invasive plants. Monitoring the manner in which biological succession proceeds in this restoration project is essential and will guide future management practices at the site. A comprehensive baseline ecological assessment completed in 2007 provides the basis for much of the ongoing and future studies.[6]

This aim of these preliminary studies was to examine the impact of the heavy metal contamination and other stresses on some key pioneering tree species, a rare metal tolerant plant, *Minuartia patula*, that grows in heavily contaminated regions such as the Lehigh Gap and abandoned mine sites, and the Pennsylvania endangered *Dicentra exima* (wild bleeding heart) that surprisingly grows abundantly in the area.

***Minuartia patula* (Sandwort)**

***Dicentra exima* (Wild bleeding heart)**

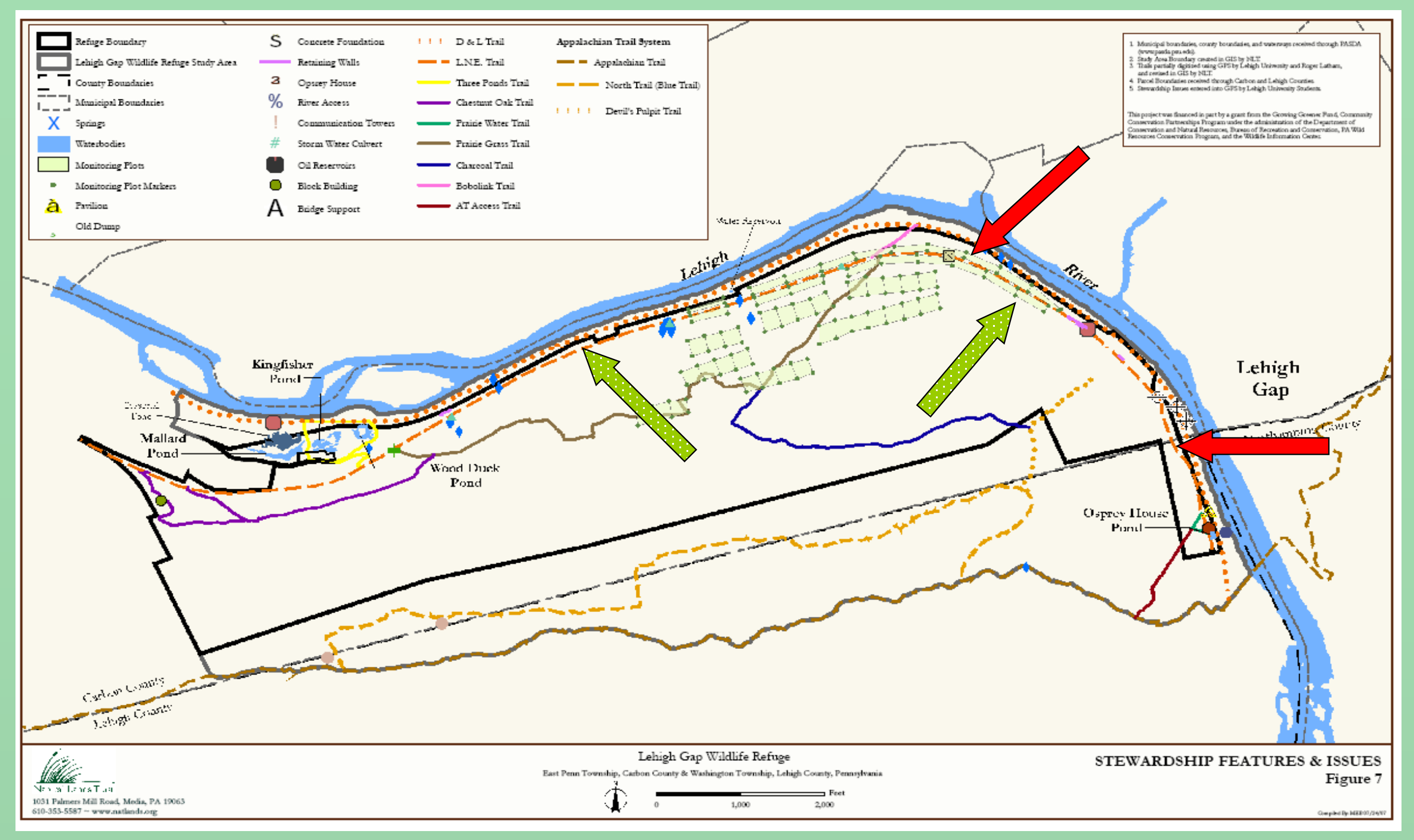

Figure 2. A map of the LGNC property (adapted from ref. 6). The original grass seeding test plots are shown as green boxes. Sampling areas for this study were between the sets of arrows: 2007 (red); 2008 sandwort studies (green).

METHODS

Vegetative tissue and soil samples were collected in the areas shown in Figure 2. Studies by others in 2004 showed that soil levels of zinc in these same sampling areas remain high to very high.[7] Samples of vegetative tissue used for zinc uptake analysis were collected along the upper railroad bed (LNE) between the red arrows in summer 2007. Sandwort population studies and sampling (May to June 2008) were conducted throughout the test plot areas and in the regions between the green arrows. Plant and soil samples were frozen until utilized for further analysis. GPS coordinates were taken for all sampling sites.

Leaf tissue was dried to constant weight in a microwave. Samples were digested in dilute HNO_3 in a CEM microwave digestor and diluted in deionized water. A Perkin Elmer AAnalyst Flame Atomic Absorption Spectrometer was used for metal analysis. Metal levels are expressed in ppm (mg zinc per kg dry tissue).

RESULTS AND DISCUSSION

A number of the pioneering species of trees show elevated levels of zinc in their leaves (see Table 1). This is consistent with the results of previous testing of plant tissues on the LGNC property.[8] 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[3], takes up relatively little zinc. Different tree species exhibit vastly different visible signs of stress.

The gray birch appears to be the most dramatically impacted tree species. Besides the leaf marginal chlorosis (see images below) which worsens throughout the growing season, the trees are stunted, leaves are ~ 50% smaller than normal, and they completely senescence and drop almost a month earlier than expected. Elevated levels of leaf phenolics (data not shown) are a possible sign of oxidative stress, but these trees are drought and nutrient stressed as well.

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

Sandwort is a non-native plant to Pennsylvania and is in the plant family of *Minuartia* known to be hyperaccumulators of metals.[9] It likely thrived in the area due to its metal tolerance property and a lack of competition from other species. With the successful establishment of other plant species and the eventual sequestration of the metal contaminants in the developing soil organic matter, it is likely that the populations of this plant will decline. During the summer of 2008, the current populations of sandwort were mapped by GPS (see Fig. 3) as a starting point to monitor any future changes.

Chlorosis in *Betula populifolia* (gray birch) leaves.

Plants sampled	Leaf zinc levels (2007-08)	Literature values for zinc levels in plants	Levels of observed plant stress
Tree species	ppm	ppm	
Gray birch	1086 ± 390 (n = 21)	330 - 1200[7]	Severe
Sweet birch	n.a.	1000[7]	High
Quaking aspen	n.a.	500 – 1100[7]	Minimal
Big tooth aspen	2200 (n = 1)	n.a.	Minimal
Sassafras	290 (n = 1)	40 - 130[7]	Moderate
Other plant species			
Wild bleeding heart	760 ± 10 (n=3)	n.a.	Negligent
Sandwort	3300 ± 1400 (n= 18)	Up to 15,000[2]	Negligent

Table 1. Zinc uptake and stress levels in vegetative tissue samples from the LGNC. Visual observations of stress were recorded in the field. Zinc levels were determined by AA analysis as described in the Methods.

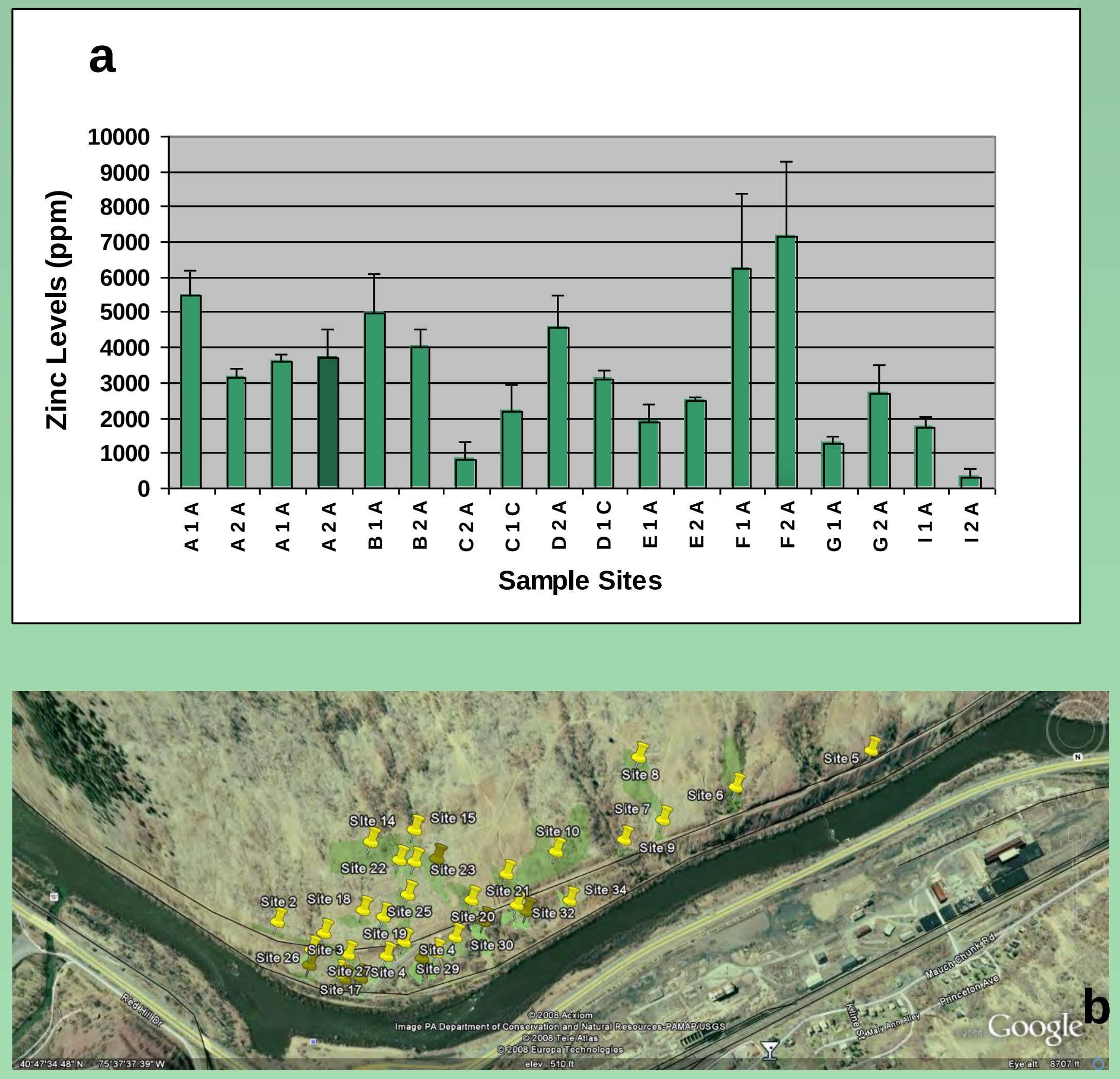

Figure 3. a) Zinc uptake in *Minuartia patula* (sandwort) taken from various sites on the LGNC property. b) Sampling sites and sandwort populations are plotted on a GoogleEarth® map using GPS coordinates. Soil samples from the same sites are currently being analyzed for zinc content.

NEXT STEPS

- **Correlate sandwort metal levels and population sizes with soil metal levels to determine if this species is indicative of the contamination status of a particular site.**
- **Monitor sandwort population sizes over time to see if this species is out-competed by warm season grasses and other successional plant species.**
- **Develop a management plan for pioneering species that accumulate heavy metals to minimize remobilization of the metal contamination.**
- **Succession analysis plots have been set up in the region of the original test plots (see Figure 2). Baseline inventories of plant species and communities are ongoing in these plots forming the basis for long-term studies of succession and biodiversity enhancement in this restoration project.**

LITERATURE CITED

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PHOTO CREDITS

H. David Husic (2008), Diane W. Husic (2007), Corey Husic (2007); used by permission.

Appendix H-1

Succession Monitoring in Grassland at Lehigh Gap Nature Center

Dan Kunkle, Lehigh Gap Nature Center; Jennifer Lansing, Arcadis BBL

Abstract

Establishment of warm-season grasses on nearly 400 acres of Lehigh Gap Nature Center (LGNC) property and more than 1,000 acres in the Palmerton vicinity has been successful. Because LGNC intends to manage their grassland area as high quality wildlife habitat, information about the successional processes occurring in the grassland is vital to adaptive management of the habitat. In order to gather that information, three pairs of succession transects have been established in the grassland area for long-term monitoring of the succession process. A protocol has been developed for quantitative and qualitative monitoring for both trees and shrubs and for total live plant cover in the transect plots. Baseline data on the plots was collected in 2008. Monitoring will continue annually for the foreseeable future.

Introduction

The Lehigh Gap Nature Center (LGNC) was established on 756± acres of land on the Kittatinny Ridge along the Lehigh River at Lehigh Gap. About 400 acres of this land was devoid of vegetation, stripped of topsoil by erosion, and contaminated to a depth of about 20 cm with heavy metals, most prominently zinc, cadmium, and lead. This was the result of more than 80 years of zinc smelting that took place at the New Jersey Zinc Company's Palmerton, PA smelters. The former West Plant of the zinc facility was across the river and upwind of the LGNC property. This land and thousands of acres in the Palmerton area were designated as a "Superfund site," and placed on the National Priorities List in 1983[1].

In the late 1980s and early 1990s, the zinc company (then called Horsehead Resources Development Company) began a remediation program on the ridge east of Lehigh Gap. Their remediation effort of close to 1,000 acres utilized a mixture of sewage sludge and fly ash spread 20 cm deep over the entire site. That was followed by planting of various species of grass and trees, some of which were not native to the area or to North America. Following the treatment, little or no effort was expended to manage the vegetative growth on the site. The site eventually turned green, but the results were not deemed to be completely satisfactory by EPA and progress on further re-vegetation efforts stalled.

In 2002-2003, the LGNC Board and staff (then called the Wildlife Information Center) purchased the properties from three private owners and became involved in efforts to re-vegetate the barren mountainside just west of Lehigh Gap. The methods developed by LGNC included no road building and employed the use of native grasses, as suggested by Bill Mineo (then of the D&L Corridor and currently an LGNC Board member), and as advised by John Dickerson (then of USDA-NRCS

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[1] USA EPA.

and currently of Finger Lakes Conservation Services). Test plots planted in 2003 using ground-based methods proved successful, as did aerial seeding tests in 2004, leading to full-scale planting of the barren acreage in 2006. Using both ground and aerial techniques developed for the test plantings, and using a refined list of grass species, the 2006 planting was done on the remainder of the approximately 400 barren acres.

This planting has been highly successful, with native grasses dominating the re-vegetated area. However, since the grasses have changed the microclimate of the site and microhabitat features of the soil, other species have colonized the grassland area, including forbs (native and non-native) and woody species, such as gray birch (*Betula populifolia*) and aspens (*Populus sp*.) Invasive species, most notably butterfly bush (*Buddleja davidii*) and Tree-of-heaven (*Ailanthus altissima*) have also colonized the site, the former so aggressively that control was needed almost from the start of the project.

Because the goal of LGNC is to manage this re-vegetated area as high quality wildlife habitat, it is imperative that we monitor the vegetative changes that are occurring on the site. We have therefore implemented a succession-monitoring plan to gather the information needed for adaptive management of the site.

Methods

In order to monitor successional changes in the re-vegetated area, permanent monitoring transects were established. 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 Appendix 1 of this report.

Baseline monitoring was done in 2008 after the transect lines were installed. Monitoring is to occur in a window from 1 August to 15 September each year. Three kinds of monitoring are to occur at each transect point – tree monitoring, shrub monitoring, and herbaceous plot/% cover monitoring.

For each of the three monitoring points in each transect line, the following protocol is to be followed with data recorded on the data sheets found in Appendix 2 of this report and plant abbreviations used are found in Appendix 3.

Tree plot monitoring. All trees (defined as tree species one meter or more in height) within a 30-meter diameter circle centered on the monitoring post are identified to species and recorded. Using a 15-meter rope affixed to the monitoring point stake, the monitoring team walks along the radius represented by the rope, recording the trees as they walk a full 360 circle around the plot. Three monitors is an optimal number for walking the radius line. A beginning point is established and a marker placed on the ground to avoid going beyond 360º and double counting trees. Monitors walk along the radius line carrying a meter stick or one of the one-meter tubes from the frame used in the herbaceous plot monitoring. Trees are recorded on the data sheet by a recorder using slash marks and totaled later.

Shrub plots monitoring. All shrubs (defined as multi-stemmed woody plants *and* trees less than 1 meter in height) within two randomly selected 10-meter diameter shrub plots are recorded. The shrub plots are selected by tossing a beanbag over the shoulder of a person standing at the monitoring post. Using the point where the beanbag lands as the pivot point, monitors use a 5-meter rope as a radius and walk 360 degrees recording every "shrub" encountered. As in the tree plot, a beginning point is to be established to avoid double counting. Monitors must carry a meter stick or one-meter tube to measure tree heights to decide whether the trees are included in the shrub count. All shrubs (multiple-stemmed, woody plants such as spiraea and elder) are to be counted regardless of height. Herbaceous plants sometimes have wood-like stems, but those stems are not persistent from year to year. Shrub stems do not die back and re-grow each year. Goldenrod is not considered a shrub, for example. As with trees, shrubs can be recorded with tally marks on the data sheet and totaled later. Whenever possible, identify the shrub species or at least genus.

Herbaceous plot monitoring and % cover. Five randomly selected herbaceous plots are monitored, with the plots selected by tossing a beanbag over the shoulder while standing at the monitoring plot point. The one-meter square frame is then placed on the ground with the beanbag at its center. From a vantage point looking straight down at the plot center, an estimate should be recorded for the amount of ground covered by live vascular plants vs. ground cover such as bare soil, rock, gravel, or un-decomposed wood. For the purposes of this study, the pioneering layer of moss and lichen that sometimes covers the ground before vascular plants become established is considered ground cover, even though it is living plant material. It is helpful to superimpose a grid over the square meter frame, or at least to imagine such a grid. Monitors should each arrive at estimates independently, and then average the estimates for the recorded percentage. Since these are estimates, precision to less than 5% intervals in not possible, so round off any averages to the nearest 5%.

After the % vascular plants and "non-living" ground cover are recorded, then each must be broken down into its component parts. For non-living, take the percentage recorded and divide it among the various components. If 30% of the ground was "non-living," you have 30 points to assign. There may be one large rock covering 20% of the test plot, so you would record 20% for solid rock. The remaining 10% can be divided up between the rest of the items. Here, you may use a value of 1 or 2% to denote a very small amount of coverage. Make sure the numbers in the ground cover category add up to the % you estimated for ground cover (in this example, 30)

Now the vascular plant cover should be recorded as well. Note that plants may be growing up next to a large rock or in bare soil and spread out over the non-living material. In this case, record whatever would be seen from a vantage point of 50 cm above the ground. If you see vegetative cover from that height, record it as vegetation. If you see the rock, record the rock. As with the ground cover, distribute the percentage points for vascular plants among the categories on the chart. Again, generally stick with 5% intervals unless there is a very small amount of a particular category and then adjust accordingly. *In addition, identify the grass species and record the dominant grass species in the plot.*

Repeat the three kinds of monitoring at the remaining monitoring points in the transect. Repeat for all transects.

Results

Succession plots were established in July 2008 with the post installed and GPS point recorded. Monitoring occurred between 21 August and 11 September 2008. These results provide the baseline for future monitoring to occur annually.

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 and in total included nearly every species we planted. Canada Wild Rye, Sand Lovegrass, and Switchgrass being 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 significant to the "shrub" content of the plots. There were an average of 36 shrubs per plot including 27 butterfly bushes and 7 young birch trees.

Birches dominated the trees recorded as well. An average of 26 trees was recorded per plot. Among those were 17 gray birch (*Betula populifolia*), 4 black birch (*Betula nigra*), 3 sassafras (*Sassafras alba*), and 1 aspen.

Discussion

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 powdery soil, which is extremely high in metals. We hypothesize that these black soil sites are partially decomposed organic matter in which decomposition was arrested as metal content (as a % 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 *Ailanthus altissima* as an exception), however, the predominant shrub is butterfly bush, another highly invasive species at this site.

We have already begun control of *Buddleja* and *Ailanthus* on this site based on observations, and the succession plot results confirm that this is indeed warranted. The appearance of birches, sassafras, and aspens is a more difficult issue. These are natives and pioneers in the natural succession process, but they also take up metals at quantities that far exceed the uptake by the grasses. 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 present us with a management question -- should we try to control the woody vegetation, perhaps with prescribed burns

The current data suggests that management with controlled burns may be desirable. Another round of monitoring in August/September 2009 will provide more information to help inform these decisions. The adaptive management process involves monitoring and decision-making based on the results of that monitoring and the goals for the site. With this succession monitoring data, we have valuable information needed for this management.

Appendix 1– Coordinates of Succession Monitoring Transect Line Pairs

Transect Lines 1E and 1W

1East Bottom	40°47'38. 00’N	75°37'19.00'W
1East A	40°47'36.00'N	75°37'19.00'W
1East B	40°47'34.00'N	75°37'18.00'W
1East C	40°47'33.00'N	75°37'18.00'W
1East Top	40°47'31.00'N	75°37'18.00'W

1West Bottom	40°47'37.00'N	75°37'23.00'W
1West A	40°47'36.00'N	75°37'23.00'W
1West B	40°47'34.00'N	75°37'23.00'W
1West C	40°47'33.00'N	75°37'23.00'W
1West Top	40°47'31.00'N	75°37'23.00'W

Transect Lines 2E and 2W

2East Bottom	40°47'32.00'N	75°37'14.00'W
2East A	40°47'29.97'N	75°37'12.96'W
2East B	40°47'28.54'N	75°37'11.46'W
2East C	40°47'27.00'N	75°37'12.00'W
2East Top	40°47'26.00'N	75°37'11.00'W

2West Bottom	40°47'30.08'N	75°37'17.00'W
2West A	40°47'29.00'N	75°37'17.00'W
2West B	40°47'27.00'N	75°37'16.00'W
2West C	40°47'26.00'N	75°37'15.00'W
2West Top	40°47'25.00'N	75°37'15.00'W

Transect Lines 1E and 1W

3East Bottom	40°47'31.00'N	75°37'48.00'W
3East A	40°47'29.00'N	75°37'48.00'W
3East B	40°47'28.00'N	75°37'47.00'W
3East C	40°47'26.00'N	75°37'47.00'W
3East Top	40°47'24.88'N	75°37'44.42'W

3West Bottom	40°47'30.00'N	75°37'51.00'W
3West A	40°47'29.00'N	75°37'50.00'W
3West B	40°47'27.00'N	75°37'50.00'W
3West C	40°47'25.00'N	75°37'49.00'W
3West Top	40°47'24.00'N	75°37'48.00'W

Note: *Bottom denotes furthest down-slope toward the river; top denotes furthest up-slope, toward the ridge top. Each transect runs approximately North-South with the bottom post furthest north.*

Appendix 2 – Succession Monitoring Data Sheets (Revised July 2010)

Date
Task **Monitoring of LGNC Succession Plots**
Personnel
Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**			Black / yellow birch	Grey birch	Aspen spp.	Sassafrass	Oak spp.	Tree of Heaven	Other	**Sum**
		Shrub Plot		Black / yellow birch	Grey birch	Aspen spp.	Sassafrass	Oak spp.	Tree of Heaven	Other	**Sum**
			x								
				Butterfly bush	Elder	Other					
			x								
		Shrub Plot		Black / yellow birch	Grey birch	Aspen spp.	Sassafrass	Oak spp.	Tree of Heaven	Other	**Sum**
			y								
				Butterfly bush	Elder	Spiraea	Sweet Fern	Other			
			y								

LIVE VEG. COVER (Herbaceous Plots)

			Herbaceous Plot	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen	% other herbaceous	**Sum (100%)**
			1								
			2								
			3								
			4								
			5								

NON-LIVING GROUND COVER (Herbaceous Plots)

			Herbaceous Plot	Total % nonliving	% solid rock > 2"	% fragmented rock < 2"	% moss	% other (soil)	% wood	% plant litter	**Sum (100%)**
			1								
			2								
			3								
			4								
			5								

Appendix 3 Succession Plot Data Abbreviation Key

Abbreviation	**Common Name**	**Scientific Name**
BBS	Big Bluestem	*Andropogan gerardii*
BBush	Butterfly Bush	*Buddleja davidii*
CG	Crab Grass Species	*Digitaria sp*
CPG	Coastal Panicgrass	*Panicum amarum*
CWR	Canada Wild Rye	*Elymus canadensis*
DT	Deertongue	*Dichanthelium clandestinum*
EGG	Eastern Gammagrass	*Tripsacum dactyloides*
EUP	Thoroughwort	*Eupatorium serotinum*
GR	Goldenrod	*Solidago sp*
HG	Hairgrass	*Deschampsia flexuosa*
IG	Indiangrass	*Sorghastrum nutans*
SG	Switchgrass	*Panicum virgatum*
SLG	Sand Lovegrass	*Eragrostis trichodes*
SR	White-snakeroot	*Eupatorium rugosum*
SW	Sandwort	*Minuartia patulem*
WLS	Whorled Loosestrife	*Lysimachia quadrifolia*

APPENDIX H-1A

Date August 21, 2008
Task **Monitoring of LGNC Succession Plots**
Personnel Dan Kunkle, Maria Tranguch, Dr. Frank Kuserk, Sarabeth Brockley
Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect #	**Tree Plot #**			Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak				Sum
1E	A				3							3
		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Butterfly Bush		Ailanthus	
1E	A		x		2	1			2		1	6
1E	A		y		2	3			2			7

LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	% live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
1E	A	SLG	1	30	25						5	30
1E	A	SW,CG	2	5	5							5
1E	A	HG	3	30	30							30
1E	A	HG	4	30	25						5	30
1E	A	BBS, SLG	5	55	45				3		7	55

Date
Task Monitoring of LGNC Succession Plots
Personnel
Transects (T1-T6); Tree Plots (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect #	**Tree Plot #**									Sum	Notes
		Shrub Plot									Notes
			x								
			y								

GROUND COVER (Herbaceous Plots)

		% non-living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
1E	A	70	1	68					2	70	5 = living w
1E	A	95	2	85				5	5	95	
1E	A	70	3	55				5	10	70	
1E	A	70	4	10					60	70	
1E	A	45	5	30		2	3	5	5	45	7=SW

Date August 21, 2008
Task **Monitoring of LGNC Succession Plots**
Personnel Dan Kunkle, Maria Tranguch, Dr. Frank Kuserk, Sara
Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**			Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Ailanthus			Sum
1E	B						4		2			6
Tree Diameter							7, 9.8,11.5,10					
		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Spirea		Butterfly Bush	
1E	B		x						2			2
1E	B		y		1						5	6

LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
1E	B	EGG, IG	1	60	60							60
1E	B	CWR,r,SLG,	2	85	85							85
1E	B	CWR, SLG	3	35	35							35
1E	B	CG	4	20	20							20
1E	B	CG	5	5	5							5

Date
Task Monitoring of LGNC Succession Plots
Personnel
Transects (T1-T6); Tree Plots (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**									Sum	Notes
		Shrub Plot									Notes
			x								
			y								

GROUND COVER (Herbaceous Plots)

		% non-living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
1E	B	40	1	25					15	40	
1E	B	15	2	7				1	7	15	
1E	B	65	3	50					15	65	
1E	B	80	4	35		5		15	25	80	
1E	B	95	5	75			10	10		95	

Date August 21, 2008
Task **Monitoring of LGNC Succession Plots**
Personnel Dan Kunkle, Maria Tranguch, Dr. Frank Kuserk, Sara
Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect #	**Tree Plot #**			Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Black Gum			Sum
1E	C				2		2	1	11			16
Tree Diameter							5.1,4.5,	3.5	10.8,5.4,6.7,6,9.5, 6,8.6,4.3,11.5,9.2			
		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Butterfly Bush		Buckthorn	
1E	C		x		1				35		1	37
1E	C		y		1				167			168

LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	% live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
1E	C	SLG,BBS,CW	1	80	77						3	80
1E	C	CWR, SLG	2	30	30							30
1E	C	HG	3	10	8						2	10
1E	C	CWR, SLG	4	80	60						20	80
1E	C	EGG, Switch	5	85	80						5	85

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Task Monitoring of LGNC Succession Plots
Personnel
Transects (T1-T6); Tree Plots (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect #	**Tree Plot #**									Sum	Notes
		Shrub Plot									Notes
			x								
			y								

GROUND COVER (Herbaceous Plots)

		% non-living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
1E	C	20	1	15		1			4	20	2=living wo
1E	C	70	2	65				3	2	70	
1E	C	90	3	50		5	5	5	25	90	1= living wo
1E	C	20	4	0				15	5	20	20= living v
1E	C	15	5	0			5		10	15	

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Task **Monitoring of LGNC Succession Plots**

Personnel Dan Kunkle, Maria Tranguch, Claire

Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**			Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak					Sum
2E	A				2	1							3

		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Butterfly Bush		Jewel Weed	Staghorn Sumac	
2E	A		x		1				13				14
2E	A		y						6		2	1	9

LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen			% other herbaceous	Sum (100%)
2E	A	CWR, DT	1	60	60								60
2E	A	CWR, HG	2	35	35								35
2E	A	IG, CWR	3	55	55								55
2E	A	CWR	4	90	90								90
2E	A	CWR, IG	5	90	90								90

Transect #	**Tree Plot #**			Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Alanthus				Sum
2E	B				5	5	1		1				12

		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Other		Sumac	Butterfly Bush	
2E	B		x						1		1		2
2E	B		y	1	2	6						3	12

LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	% live veg	% live grass	% fern	% black birch	% grey birch	% aspen			% other herbaceous	Sum (100%)
2E	B	CWR, BBS	1	50	50								50
2E	B	BBS	2	45	45								45
2E	B	Cwr, DT, Swi	3	85	85								85
2E	B	CWR	4	50	50								50
2E	B	Switch	5	65	65								65

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Task Monitoring of LGNC Succession Plots

Personnel

Transects (T1-T6); Tree Plots (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**									Sum

		Shrub Plot								
			x							
			y							

GROUND COVER (Herbaceous Plots)

		% Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)
2E	A	40	1	25					15	40
2E	A	65	2	60					5	65
2E	A	45	3	45						45
2E	A	10	4						10	10
2E	A	10	5	5					5	10

Transect #	**Tree Plot #**									Sum

		Shrub Plot								
			x							
			y							

GROUND COVER (Herbaceous Plots)

		% non-living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)
2E	B	50	1	50						50
2E	B	55	2	50					5	55
2E	B	15	3	10					5	15
2E	B	50	4	25	10		5		10	50
2E	B	35	5	10					25	35

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Task **Monitoring of LGNC Succession Plots**

Personnel Dan Kunkle, Maria Tranguch, Claire

Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**			Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Black Gum			Sum
2E	C			6	3		1		2			12
Tree Diameter							5.09		5.73, 3.18			
		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Sumac		Butterfly Bush	
2E	C		x	2					1			3
2E	C		y	5	2		2		1		2	12

LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
2E	C	CWR	1	5	5							5
2E	C	NONE	2	0								0
2E	C	CWR	3	1	1							1
2E	C	SLG	4	5	5							5
2E	C	HG	5	75	75							75

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Task Monitoring of LGNC Succession Plots

Personnel

Transects (T1-T6); Tree Plots (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**									Sum	Notes
		Shrub Plot									Notes
			x								
			y								

GROUND COVER (Herbaceous Plots)

		% Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
2E	C	95	1	70			20	5		95	
2E	C	100	2	85				15		100	
2E	C	99	3	95			2	2		99	
2E	C	95	4	65			25	5		95	25=Black S
2E	C	25	5	15			5	5		25	

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Task **Monitoring of LGNC Succession Plots**
Personnel : Dan Kunkle, Maria Tranguch
Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**			Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Black Gum			Sum
3E	A				10				1			11
Tree Diamete	A								10			

		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Butterfly Bush	Spirea	Ailanthus	
3E	A		x	3	6	1			47	1		58
3E	A		y	1	4				231		3	239

LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
3E	A	SLG	1	5	5							5
3E	A	BBS, CWR, S	2	80	70						10	80
3E	A	BBS, Switch	3	70	50						20	70
3E	A	SLG	4	30	15						15	30
3E	A	SLG, CWR	5	20	15						5	20

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Task Monitoring of LGNC Succession Plots
Personnel
Transects (T1-T6); Tree Plots (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**									Sum	Notes
3E	A										
3E	A										

		Shrub Plot									
3E	A		x								
3E	A		y								

GROUND COVER (Herbaceous Plots)

		% Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
3E	A	95	1	90			3		2	95	
3E	A	20	2	5				15		20	5 =Bbush
3E	A	30	3				10	5	15	30	20=SR, GR, V
3E	A	70	4	5	25		25		15	70	15=EUP, Rag
3E	A	80	5	3				2	75	80	3 =SW 2 =Bb

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Transect	**Tree Plot**			Black / yellow birch	Grey birch	Aspen	Sassafrass	Chestnut Oak				Sum
3E	B				30			1				31
Tree Diameter								5				

		Shrub Plot		Black / yellow birch	Grey birch	Quaking Aspen	Sassafrass	__ Oak	Butterfly Bush			
3E	B		x	1	2	1			72			76
3E	B		y	1	7	1			60			69

LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
3E	B	SLG, BBS	1	60	58						2	60
3E	B	BBS, IG	2	35	34				1			35
3E	B	BBS, SLG	3	50	30			20				50
3E	B	CWR, Switch	4	95	95							95
3E	B	CWR	5	35	32						3	35

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Task Monitoring of LGNC Succession Plots
Personnel
Transects (T1-T6); Tree Plots (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**									Sum	Notes

		Shrub Plot									
			x								
			y								

GROUND COVER (Herbaceous Plots)

		%Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
		40	1	15	1	5	5	4	10	40	
		65	2	55				4	6	65	
		50	3	45					5	50	
		5	4						5	5	
		65	5	15				10	40	65	

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Task **Monitoring of LGNC Succession Plots**
Personnel Dan Kunkle, Maria Tranguch
Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**			Black / yellow birch	Grey birch	Aspen	Sassafrass	Chestnut Oak				Sum
3E	C			3	1		13	3				20
Tree Diameter							4.7,4.7,6,3.2,1.3,3,4.5,4.8,4.8,7.6,3.2	7,3.2,7				

		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Ailanthus	Butterfly Bush		
3E	C		x		1		1		1	2		5
			y		2					2		4

LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
3E	C	NONE	1	20	10		10					20
3E	C	Switch, EGG	2	100	100							100
3E	C	SLG, CWR	3	65	65							65
3E	C	SLG	4	10	10							10
3E	C	SLG	5	30	30							30

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Task Monitoring of LGNC Succession Plots
Personnel
Transects (T1-T6); Tree Plots (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**									Sum	Notes
3E	C										

		Shrub Plot									
3E	C		x								
3E	C		y								

GROUND COVER (Herbaceous Plots)

		% Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
3E	C	80	1	45				25	10	80	CPG, SLG,
3E	C	0	2							0	
3E	C	35	3	30				5		35	
3E	C	90	4	80		3	2	5		90	
3E	C	70	5	60			5	5		70	

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Personnel Dan Kunkle, Maria Tranguch, Dr. Frank Kuserk, Sara
Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**			Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak				Sum
1W	A											0

		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Ailanthus			
1W	A		x						2			2
1W	A		y									0

A
LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
1W	A	CWR	1	40	35						5	40
1W	A	SLG	2	15	15							15
1W	A	SLG	3	40	40							40
1W	A	CWR	4	90	90							90
1W	A	CWR, SLG	5	80	80							80

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Task Monitoring of LGNC Succession Plots
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Transect	**Tree Plot**									Sum	Notes

		Shrub Plot									Notes
			x								
			y								

GROUND COVER (Herbaceous Plots)

		% Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
1W	A	60	1	40	5		5	2	8	60	5=SW, frag
1W	A	85	2	30	25	2	18	5	5	85	fragmented
1W	A	60	3	55				2	3	60	
1W	A	10	4						10	10	
1W	A	20	5	15				2	3	20	

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Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**			Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak				Sum
1W	B				83	13						96

		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Butterfly Bush	Spirea	Ailanthus	
1W	B		x		12	3			19	1	1	36
1W	B		y		23				28	2	1	54

LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen	%Butterfly Bush	% other herbaceous	Sum (100%)
1W	B	BBS	1	60	58			2				60
1W	B	CWR, SLG	2	75	65			10				75
1W	B	SLG	3	35	35							35
1W	B	EGG, BBS	4	75	75							75
1W	B	SLG	5	25	20					5		25

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Task Monitoring of LGNC Succession Plots
Personnel
Transects (T1-T6); Tree Plots (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**									Sum	Notes

		Shrub Plot									Notes
			x								
			y								

GROUND COVER (Herbaceous Plots)

		% Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
1W	B	40	1	38				2		40	
1W	B	25	2	5				20		25	
1W	B	65	3	50				15		65	
1W	B	25	4	5			3	5	12	25	
1W	B	75	5	75						75	

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Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**			Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Black Gum			Sum
1W	C				3				1			4
Tree Diameter									10			

		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Ailanthus	Butterfly Bush		
1W	C		x		2				2	6		10
1W	C		y						1	18		19

LIVE VEG. COVER (Herbaceous Plots)

			Herbaceous Plot	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
1W	C		1	25	25							25
1W	C		2	25	10						15	25
1W	C		3	55	55							55
1W	C		4	80	20						60	80
1W	C		5	85	84						1	85

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Task Monitoring of LGNC Succession Plots
Personnel
Transects (T1-T6); Tree Plots (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**									Sum	Notes

		Shrub Plot									Notes
			x								
			y								

GROUND COVER (Herbaceous Plots)

		% Non-living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
1W	C	75	1	40				5	30	75	
1W	C	75	2	15	5	5	10	30	10	75	15 =SW
1W	C	45	3	45						45	
1W	C	20	4	5				5	10	20	60 = SW
1W	C	15	5	3	2		5		5	15	

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Task **Monitoring of LGNC Succession Plots**

Personnel Dan Kunkle, Maria Tranguch, Claire

Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**			Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak				Sum
2W	A			46			15					61
Tree Diameter				5.7,6.5,9.7			11.6,5.4,6.7,3.7,5.3,6.7,11.8,4,5.6,4.6,7.3,5.3,10.2					

		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak				
2W	A		x	4								4
2W	A		y	21	1							22

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Task Monitoring of LGNC Succession Plots

Personnel

Transects (T1-T6); Tree Plots (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**									Sum	Notes

		Shrub Plot									Notes
			x								
			y								

LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
2W	A	CWR,SLG	1	55	55							55
2W	A	CWR,SLG	2	40	30		10					40
2W	A	HG, SLG,CW	3	80	80							80
2W	A	HG	4	5	5							5
2W	A	BBLUE	5	20	5		15					20

GROUND COVER (Herbaceous Plots)

		% Non-Liviing	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
2W	A	45	1	38			2	5		45	
2W	A	60	2	40				15	5	60	
2W	A	20	3	10			10			20	
2W	A	95	4	30			60	5		95	
2W	A	80	5	40		5	35			80	

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Task **Monitoring of LGNC Succession Plots**

Personnel Dan Kunkle, Maria Tranguch, Claire

Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**			Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak				Sum
2W	B			5	3	2	1					11
Tree Diameter							2.4					

		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Butterfly Bush	Winged Sumac		
2W	B		x	10	4	13			3			30
2W	B		y	9		15			3	1		28

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Task Monitoring of LGNC Succession Plots

Personnel

Transects (T1-T6); Tree Plots (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**									Sum	Notes

		Shrub Plot									
			x								
			y								

LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
2W	B	DT, CWR	1	95	94	1						95
2W	B	SLG	2	2	2							2
2W	B	NONE	3	0								0
2W	B	CWR,DT	4	75	75							75
2W	B	CWR,DT	5	90	90							90

GROUND COVER (Herbaceous Plots)

		%Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
2W	B	5	1	2.5					2.5	5	
2W	B	98	2	95			3			98	
2W	B	100	3	95				5		100	
2W	B	25	4	25						25	
2W	B	10	5	10						10	

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Task **Monitoring of LGNC Succession Plots**

Personnel Dan Kunkle, Maria Tranguch, Claire

Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**			Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Other			Sum
2W	C			18	3	2	3		1			27
Tree Diameter				4			5.1,2.9,7					

		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak				
2W	C		x	3								3
2W	C		y	5	1	1						7

Date

Task Monitoring of LGNC Succession Plots

Personnel

Transects (T1-T6); Tree Plots (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**									Sum	Notes

		Shrub Plot									Notes
			x								
			y								

LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen	Butterfly Bush	% other herbaceous	Sum (100%)
2W	C	CWR,DT,SLG	1	15	10					5		15
2W	C	BBLUE,IG,DT	2	50	50							50
2W	C	NONE	3	0								0
2W	C	NONE	4	0								0
2W	C	NONE	5	0								0

GROUND COVER (Herbaceous Plots)

		%Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
2W	C	85	1	72			5	5	3	85	
2W	C	50	2	30			5	15		50	
2W	C	100	3	85			10	5		100	
2W	C	100	4	85				15		100	
2W	C	100	5	95			2.5	2.5		100	

Date September 4, 2008
Task **Monitoring of LGNC Succession Plots**
Personnel Dan Kunkle, Maria Tranguch
Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**			Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak				Sum
3W	A				28		2					30
Tree Diameter							5.3,4.6					

		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Butterfly Bush	Ailanthus		
3W	A		x	1	8				95	1		105
3W	A		y		3				30	5		38

LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen	Butterfly Bush	% other herbaceous	Sum (100%)
3W	A	SLG,BBS	1	85	80					3	2	85
3W	A	SLG,SWITCH	2	80	75			2	1		2	80
3W	A	BBUSH,SR,S	3	75	15					40	20	75
3W	A	SLG	4	25	15					10		25
3W	A	IG,SLG	5	70	35						35	70

Date
Task Monitoring of LGNC Succession Plots
Personnel
Transects (T1-T6); Tree Plots (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**									Sum	Notes

		Shrub Plot									Notes
			x								
			y								

GROUND COVER (Herbaceous Plots)

		% Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
3W	A	15	1					2	13	15	2 =SR
3W	A	20	2	8			5	2	5	20	2 = EUP, W
3W	A	25	3	10					15	25	20 =SR
3W	A	75	4	45				10	20	75	
3W	A	30	5	5				5	20	30	35=EUP,SI

Date September 4, 2008
Task **Monitoring of LGNC Succession Plots**
Personnel Dan Kunkle, Maria Tranguch
Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**			Black / yellow birch	Grey birch	Aspen	Sassafrass	Chestnut Oak				Sum
3W	B				40		3	1				44
							6.5,13,15	16				

		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Butterfly Bush			
3W	B		x	2	18		1		16			37
3W	B		y	1	6				24			31

LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen	Butterfly Bush	% other herbaceous	Sum (100%)
3W	B	EGG,SLG	1	65	45	5		10			5	65
3W	B	SLG,GB	2	75	70			5				75
3W	B	SW,SLG	3	70	40						30	70
3W	B	NONE	4	75	70					5		75
3W	B	SG,BBLUE,IC	5	90	65						25	90

Date
Task Monitoring of LGNC Succession Plots
Personnel
Transects (T1-T6); Tree Plots (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**									Sum	Notes

		Shrub Plot									Notes
			x								
			y								

GROUND COVER (Herbaceous Plots)

		%Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
3W	B	35	1	10			2	3	20	35	5=SR,GR
3W	B	25	2	2	1		1	1	20	25	
3W	B	30	3	28					2	30	30=SW
3W	B	25	4	5				1	19	25	SG,BBLUE
3W	B	10	5	5					5	10	25=EUP,SI

Date September 4, 2008
Task **Monitoring of LGNC Succession Plots**
Personnel Dan Kunkle, Maria Tranguch
Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**			Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak				Sum
3W	C			2	86							88

		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak	Butterfly Bush			
3W	C		x	4	35				40			79
3W	C		y		28				37			65

LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen	Butterfly Bush	% other herbaceous	Sum (100%)
3W	C	SG	1	80	75						5	80
3W	C	BBLUE	2	40	15					15	10	40
3W	C	BBLUE, IG, S	3	70	70							70
3W	C	NONE	4	90	80	2				5	3	90
3W	C	SLG,BBLUE,	5	30	20			8		1	1	30

Date
Task Monitoring of LGNC Succession Plots
Personnel
Transects (T1-T6); Tree Plots (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**									Sum	Notes

		Shrub Plot									Notes
			x								
			y								

GROUND COVER (Herbaceous Plots)

		%Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
		20	1	10					10	20	5=SR
		60	2	23	2				35	60	10=WLS
		30	3	27					3	30	
		10	4	5					5	10	3=SR,GR
		70	5	50	15			5		70	1=sr,wild c

Date

Task **Monitoring of LGNC Succession Plots**

Personnel

Transects (T1-T6); 15m circles (trees) (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**			Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak				Sum

		Shrub Plot		Black / yellow birch	Grey birch	Aspen	Sassafrass	__ Oak				
			x									
			y									

				LIVE VEG. COVER (Herbaceous Plots)								
			Herbaceous Plot	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
			1	0								0
			2	0								0
			3	0								0
			4	0								0
			5	0								0

Date

Task Monitoring of LGNC Succession Plots

Personnel

Transects (T1-T6); Tree Plots (A,B,C); Shrub Plots (x, y); Herbaceous Plots (1-5)

Transect	**Tree Plot**									Sum	Notes

		Shrub Plot									Notes
			x								
			y								

				GROUND COVER (Herbaceous Plots)							
			Herbaceous Plot	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
			1							0	
			2							0	
			3							0	
			4							0	
			5							0	

Assessment Area	Data	Total
601	Average of % live veg	36.75
	Average of % live grass	15.66666667
	Average of % fern	
	Average of % black birch	25
	Average of % grey birch	25
	Average of % aspen	
	Average of % other herbaceous	
604	Average of % live veg	47.5
	Average of % live grass	47.5
	Average of % fern	
	Average of % black birch	
	Average of % grey birch	
	Average of % aspen	
	Average of % other herbaceous	
606	Average of % live veg	62.5
	Average of % live grass	
	Average of % fern	
	Average of % black birch	
	Average of % grey birch	
	Average of % aspen	
	Average of % other herbaceous	
607	Average of % live veg	63.75
	Average of % live grass	56.25
	Average of % fern	
	Average of % black birch	15
	Average of % grey birch	
	Average of % aspen	
	Average of % other herbaceous	
609	Average of % live veg	62.5
	Average of % live grass	
	Average of % fern	
	Average of % black birch	
	Average of % grey birch	
	Average of % aspen	
	Average of % other herbaceous	
610	Average of % live veg	60
	Average of % live grass	
	Average of % fern	25
	Average of % black birch	66.66666667
	Average of % grey birch	15
	Average of % aspen	
	Average of % other herbaceous	
613	Average of % live veg	68.75
	Average of % live grass	
	Average of % fern	
	Average of % black birch	
	Average of % grey birch	
	Average of % aspen	
	Average of % other herbaceous	
615	Average of % live veg	23.75
	Average of % live grass	
	Average of % fern	
	Average of % black birch	
	Average of % grey birch	
	Average of % aspen	
	Average of % other herbaceous	
616	Average of % live veg	57.5
	Average of % live grass	
	Average of % fern	
	Average of % black birch	
	Average of % grey birch	
	Average of % aspen	
	Average of % other herbaceous	
619	Average of % live veg	62.5
	Average of % live grass	
	Average of % fern	
	Average of % black birch	
	Average of % grey birch	
	Average of % aspen	
	Average of % other herbaceous	
OP2-631	Average of % live veg	7.5
	Average of % live grass	
	Average of % fern	
	Average of % black birch	
	Average of % grey birch	
	Average of % aspen	
	Average of % other herbaceous	
OP2-632	Average of % live veg	11.25
	Average of % live grass	
	Average of % fern	
	Average of % black birch	
	Average of % grey birch	
	Average of % aspen	
	Average of % other herbaceous	
OP2-633	Average of % live veg	23.75
	Average of % live grass	
	Average of % fern	
	Average of % black birch	
	Average of % grey birch	
	Average of % aspen	
	Average of % other herbaceous	
OP2-634	Average of % live veg	17.5
	Average of % live grass	
	Average of % fern	
	Average of % black birch	
	Average of % grey birch	
	Average of % aspen	
	Average of % other herbaceous	
Total Average of % live veg		43.25
Total Average of % live grass		42
Total Average of % fern		25
Total Average of % black birch		38.125
Total Average of % grey birch		20
Total Average of % aspen		
Total Average of % other herbaceous		

APPENDIX H-1B

Cumulative Succession Data 2008

Tree Plots

Transect #	**Tree Plot #**	Black birch	Grey birch	Aspen	Sassafrass	Oak	Ailanthus	Black Gum	Other	Sum
1E	A		3							3
1E	B				4		2			6
1E	C		2		2	1		11		16
1W	A									0
1W	B		83	13						96
1W	C		3					1		4
2E	A		2	1						3
2E	B		5	5	1		1			12
2E	C	6	3		1			2		12
2W	A	46			15					61
2W	B	5	3	2	1					11
2W	C	18	3	2	3				1	27
3E	A		10					1		11
3E	B		30			1				31
3E	C	3	1		13	3				20
3W	A		28		2					30
3W	B		40		3	1				44
3W	C	2	86							88
Totals		**80**	**302**	**23**	**45**	**6**	**3**	**15**	**1**	**475**
Per plot		**4**	**17**	**1**	**3**	**0**	**0**	**1**	**0**	**26**

Cumulative Succession Data 2008

Shrub Plots 2008

		Shrub Plot		Black birch	Grey birch	Aspen	Sassafrass	Oak	Butterfly Bush	Ailanthus	Spirea	Buckthorn	Sumac	Other	Total Shrubs
1E	A		x		2	1			2	1					6
1E	A		y		2	3			2						7
1W	A		x							2					2
1W	A		y												0
1E	B		x								2				2
1E	B		y		1				5						6
1W	B		x		12	3			19	1	1				36
1W	B		y		23				28	1	2				54
1E	C		x		1				35			1			37
1E	C		y		1				167						168
1W	C		x		2				6	2					10
1W	C		y						18	1					19
2E	A		x		1				13						14
2E	A		y						6				1	2	9
2W	A		x	4											4
2W	A		y	21	1										22
2E	B		x										1	1	2
2E	B		y	1	2	6			3						12
2W	B		x	10	4	13			3						30
2W	B		y	9		15			3				1		28
2E	C		x	2									1		3
2E	C		y	5	2		2		2				1		12
2W	C		x	3											3
2W	C		y	5	1	1									7
3E	A		x	3	6	1			47		1				58
3E	A		y	1	4				231	3					239
3W	A		x	1	8				95	1					105
3W	A		y		3				30	5					38
3E	B		x	1	2	1			72						76

3E	B		y	1	7	1			60						69
3W	B		x	2	18		1		16						37
3W	B		y	1	6				24						31
3E	C		x		1		1		2	1					5
3E	C		y		2				2						4
3W	C		x	4	35				40						79
3W	C		y		28				37						65
Totals				74	175	45	4	0	968	18	6	1	5	3	1299
Per plot				2.1	4.9	1.3	0.1	0.0	26.9	0.5	0.2	0.0	0.1	0.1	36.1
		Shrub Plot		Black birch	Grey birch	Aspen	Sassafrass	Oak	Butterfly Bush	Ailanthus	Spirea	Buckthorn	Sumac	Other	Total Shrubs

Cumulative Succession Data 2008

Vegetative Cover Plots

LIVE VEG. COVER (Herbaceous Plots)

		Dominant Species	**Herbaceous Plot**	% live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
1E	A	SLG	1	30	25						5	30
1E	A	SW,CG	2	5	5							5
1E	A	HG	3	30	30							30
1E	A	HG	4	30	25						5	30
1E	A	BBS, SLG	5	55	45				3		7	55

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
1E	B	EGG, IG	1	60	60							60
1E	B	CWR,r,SLG, BBS	2	85	85							85
1E	B	CWR, SLG	3	35	35							35
1E	B	CG	4	20	20							20
1E	B	CG	5	5	5							5

		Dominant Species	**Herbaceous Plot**	% live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
1E	C	SLG,BBS,CWR	1	80	77						3	80
1E	C	CWR, SLG	2	30	30							30
1E	C	HG	3	10	8						2	10
1E	C	CWR, SLG	4	80	60						20	80
1E	C	EGG, Switch	5	85	80						5	85

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
1W	A	CWR	1	40	35						5	40
1W	A	SLG	2	15	15							15
1W	A	SLG	3	40	40							40
1W	A	CWR	4	90	90							90
1W	A	CWR, SLG	5	80	80							80

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen	%Butterfly Bush	% other herbaceous	Sum (100%)
1W	B	BBS	1	60	58			2				60
1W	B	CWR, SLG	2	75	65			10				75
1W	B	SLG	3	35	35							35
1W	B	EGG, BBS	4	75	75							75
1W	B	SLG	5	25	20					5		25

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
1W	C	SLG	1	25	25							25
1W	C	SW, CG	2	25	10						15	25
1W	C	CWR	3	55	55							55
1W	C	SW, CWR	4	80	20						60	80
1W	C	CWR	5	85	84						1	85

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
2E	A	CWR, DT	1	60	60							60
2E	A	CWR, HG	2	35	35							35
2E	A	IG, CWR	3	55	55							55
2E	A	CWR	4	90	90							90
2E	A	CWR, IG	5	90	90							90

		Dominant Species	**Herbaceous Plot**	% live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
2E	B	CWR, BBS	1	50	50							50
2E	B	BBS	2	45	45							45

2E	B	Cwr, DT, Switch	3	85	85							85
2E	B	CWR	4	50	50							50
2E	B	Switch	5	65	65							65

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
2E	C	CWR	1	5	5							5
2E	C	NONE	2	0								0
2E	C	CWR	3	1	1							1
2E	C	SLG	4	5	5							5
2E	C	HG	5	75	75							75

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
2W	A	CWR,SLG	1	55	55							55
2W	A	CWR,SLG	2	40	30		10					40
2W	A	HG, SLG,CWR	3	80	80							80
2W	A	HG	4	5	5							5
2W	A	BBLUE	5	20	5		15					20

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
2W	B	DT, CWR	1	95	94	1						95
2W	B	SLG	2	2	2							2
2W	B	NONE	3	0								0
2W	B	CWR,DT	4	75	75							75
2W	B	CWR,DT	5	90	90							90

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen	Butterfly Bush	% other herbaceous	Sum (100%)
2W	C	CWR,DT,SLG	1	15	10					5		15
2W	C	BBLUE,IG,DT	2	50	50							50
2W	C	NONE	3	0								0
2W	C	NONE	4	0								0
2W	C	NONE	5	0								0

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
3E	A	SLG	1	5	5							5
3E	A	BBS, CWR, SLG	2	80	70						10	80
3E	A	BBS, Switch	3	70	50						20	70
3E	A	SLG	4	30	15						15	30
3E	A	SLG, CWR	5	20	15						5	20

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
3E	B	SLG, BBS	1	60	58						2	60
3E	B	BBS, IG	2	35	34				1			35
3E	B	BBS, SLG	3	50	30			20				50
3E	B	CWR, Switch, SL	4	95	95							95
3E	B	CWR	5	35	32						3	35

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen		% other herbaceous	Sum (100%)
3E	C	NONE	1	20	10		10					20
3E	C	Switch, EGG	2	100	100							100
3E	C	SLG, CWR	3	65	65							65
3E	C	SLG	4	10	10							10
3E	C	SLG	5	30	30							30

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen	Butterfly Bush	% other herbaceous	Sum (100%)
3W	A	SLG,BBS	1	85	80					3	2	85
3W	A	SLG,SWITCH	2	80	75			2	1		2	80
3W	A	BBUSH,SR,SLG	3	75	15					40	20	75
3W	A	SLG	4	25	15					10		25

3W	A	IG,SLG	5	70	35						35	70

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen	Butterfly Bush	% other herbaceous	Sum (100%)
3W	B	EGG,SLG	1	65	45	5		10			5	65
3W	B	SLG,GB	2	75	70			5				75
3W	B	SW,SLG	3	70	40						30	70
3W	B	NONE	4	75	70					5		75
3W	B	SG,BBLUE,IG	5	90	65						25	90

		Dominant Species	**Herbaceous Plot**	Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen	Butterfly Bush	% other herbaceous	Sum (100%)
3W	C	SG	1	80	75						5	80
3W	C	BBLUE	2	40	15					15	10	40
3W	C	BBLUE, IG, Switc	3	70	70							70
3W	C	NONE	4	90	80	2				5	3	90
3W	C	SLG,BBLUE, IG	5	30	20			8		1	1	30

		Dominant Species		Total % live veg	% live grass	% fern	% black birch	% grey birch	% aspen	Butterfly Bush	% other herbaceous	Sum (100%)
Averages				**49**	**43**	**0**	**0**	**1**	**0**	**1**	**4**	

NOTE: 83% of the ground was covered by solid rock or live vegetation. 88% of the vegetation was live grass.

GROUND COVER (Herbaceous Plots)

		% non-living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
1E	A	70	1	68					2	70	5 = living woody
1E	A	95	2	85				5	5	95	
1E	A	70	3	55				5	10	70	
1E	A	70	4	10					60	70	
1E	A	45	5	30		2	3	5	5	45	7=SW

		% non-living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
1E	B	40	1	25					15	40	
1E	B	15	2	7				1	7	15	
1E	B	65	3	50					15	65	
1E	B	80	4	35		5		15	25	80	
1E	B	95	5	75			10	10		95	

		% non-living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
1E	C	20	1	15		1			4	20	2=living woody
1E	C	70	2	65				3	2	70	
1E	C	90	3	50		5	5	5	25	90	1= living woody
1E	C	20	4	0				15	5	20	20= living woody
1E	C	15	5	0			5		10	15	

		% Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
1W	A	60	1	40	5		5	2	8	60	5=SW, frag rock <2"
1W	A	85	2	30	25	2	18	5	5	85	frag bark = other
1W	A	60	3	55				2	3	60	
1W	A	10	4						10	10	
1W	A	20	5	15				2	3	20	

		% Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes

1W	B	40	1	38				2		40	
1W	B	25	2	5				20		25	
1W	B	65	3	50				15		65	
1W	B	25	4	5			3	5	12	25	
1W	B	75	5	75						75	

		% Non-living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
1W	C	75	1	40				5	30	75	
1W	C	75	2	15	5	5	10	30	10	75	15 =SW
1W	C	45	3	45						45	
1W	C	20	4	5				5	10	20	60 = SW
1W	C	15	5	3	2		5		5	15	

		% Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
2E	A	40	1	25					15	40	
2E	A	65	2	60					5	65	
2E	A	45	3	45						45	
2E	A	10	4						10	10	
2E	A	10	5	5					5	10	

		% non-living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
2E	B	50	1	50						50	
2E	B	55	2	50					5	55	
2E	B	15	3	10					5	15	
2E	B	50	4	25	10		5		10	50	
2E	B	35	5	10					25	35	

		% Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
2E	C	95	1	70			20	5		95	
2E	C	100	2	85				15		100	
2E	C	99	3	95			2	2		99	
2E	C	95	4	65			25	5		95	25=Black Soil
2E	C	25	5	15			5	5		25	

		% Non-Liviing	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
2W	A	45	1	38			2	5		45	
2W	A	60	2	40				15	5	60	
2W	A	20	3	10			10			20	
2W	A	95	4	30			60	5		95	
2W	A	80	5	40		5	35			80	

		%Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
2W	B	5	1	2.5					2.5	5	
2W	B	98	2	95			3			98	
2W	B	100	3	95				5		100	
2W	B	25	4	25						25	
2W	B	10	5	10						10	

		%Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
2W	C	85	1	72			5	5	3	85	
2W	C	50	2	30			5	15		50	

2W	C	100	3	85			10	5		100	
2W	C	100	4	85				15		100	
2W	C	100	5	95			2.5	2.5		100	

		% Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
3E	A	95	1	90			3		2	95	
3E	A	20	2	5				15		20	5 =Bbush
3E	A	30	3				10	5	15	30	20=SR, GR, WLS, Bbush
3E	A	70	4	5	25		25		15	70	15=EUP, Ragweed
3E	A	80	5	3				2	75	80	3 =SW 2 =Bbush

		%Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
3E	B	40	1	15	1	5	5	4	10	40	
3E	B	65	2	55				4	6	65	
3E	B	50	3	45					5	50	
3E	B	5	4						5	5	
3E	B	65	5	15				10	40	65	

		% Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
3E	C	80	1	45				25	10	80	CPG, SLG, CWR (dom. Species)
3E	C	0	2							0	
3E	C	35	3	30				5		35	
3E	C	90	4	80		3	2	5		90	
3E	C	70	5	60			5	5		70	

		% Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
3W	A	15	1					2	13	15	2 =SR
3W	A	20	2	8			5	2	5	20	2 = EUP, WLS
3W	A	25	3	10					15	25	20 =SR
3W	A	75	4	45				10	20	75	
3W	A	30	5	5				5	20	30	35=EUP,SR

		%Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
3W	B	35	1	10			2	3	20	35	5=SR,GR
3W	B	25	2	2	1		1	1	20	25	
3W	B	30	3	28					2	30	30=SW
3W	B	25	4	5				1	19	25	SG,BBLUE,EG,IG,SLG
3W	B	10	5	5					5	10	25=EUP,SR

		%Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
3W	C	20	1	10					10	20	5=SR
3W	C	60	2	23	2				35	60	10=WLS
3W	C	30	3	27					3	30	
3W	C	10	4	5					5	10	3=SR,GR
3W	C	70	5	50	15			5		70	1=sr,wild cenule

		%Non-Living	**Herbaceous Plot**	% solid rock	% fragmented rock	% moss	% other (soil)	% wood	% grass litter	Sum (100%)	Notes
		51		**34**	**1**	**0**	**3**	**4**	**8**		

Succession Plot Data Abbreviation Key

Abbreviation	Common Name	Scientific Name
BBS	Big Bluestem	*Andropogan gerardii*
BBush	Butterfly Bush	*Buddleja davidii*
CG	Crab Grass Species	*Digitaria sp*
CPG	Coastal Panicgrass	*Panicum amarum*
CWR	Canada Wild Rye	*Elymus canadensis*
DT	Deertongue	*Dichanthelium clandestinum*
EGG	Eastern Gammagrass	*Tripsacum dactyloides*
EUP	Thoroughwort	*Eupatorium serotinum*
GR	Goldenrod	*Solidago sp*
HG	Hairgrass	*Deschampsia flexuosa*
IG	Indiangrass	*Sorghastrum nutans*
SG	Switchgrass	*Panicum virgatum*
SLG	Sand Lovegrass	*Eragrostis trichodes*
SR	White-snakeroot	*Eupatorium rugosum*
SW	Sandwort	*Minuartia patulem*
WLS	Whorled Loosestrife	*Lysimachia quadrifolia*

APPENDIX H-2

Ed Succession Test Plot				**Occurrence**		
Plant Inventory 5/22/08				Abundant	**A**	Many plants throughout plot
			Number	Common	**C**	Scattered clumps of plants
Common name	***Scientific name***	**Occurrence**	**of plants**	Occasional		or a few throughout
Grass, cool season sp.		A	very many	Rare	**O**	Few to moderate in limited area
Grass, warm season sp.		C	many		**R**	1 to 3 plants
Indian Grass	*Sorghastrum nutans*	O				
Little Bluestem	*Schyzacharum scoparium*	O				
Gray Birch	*Betula populifolia*	C	35			
Black Birch	*Betula nigra*	R	1			
European White Birch	*Betula pendula*	R	1			
Bigtooth Aspen	*Populus grandidentata*	C	24			
Quaking Aspen	*Populus tremuloides*	O	5			
Willow sp.	*Salix sp.*	C	22			
Sassafras	*Sassafras albidum*	C	11			
Catalpa	*Catalpa bignonioides*	R	1			
Buckthorn	*Rhamnus frangula*	R	1			
Butterfly bush	*Buddleja davidii*	O	5			
Staghorn Sumac	*Rhus typhina*	O	4			
Eupatorium	*Eupatorium lanceolata*	C	many	one area only		
White Snakeroot	*Eupatorium rugosum*	R	1			
Thrift	*Armeria maratima*	R	2			
Crown vetch	*Securigera varia*	R	1			
Hay-scented forn	*Dennstaedtia punctiloba*	R	3			
Moss sp		R		2 or 3 patches		

Appendix H-3

Lehigh Gap Nature Center -- Grassland Restoration Project

Total Cover Analysis Activity

Background

The Wildlife Information Center (now known as Lehigh Gap Nature Center, or LGNC)) purchased 750 acres of land on the Kittatinny Ridge (Blue Mt.), near Palmerton, PA. Of that acreage, about half (350-400 acres) was totally barren as the result of air pollution from zinc smelting in Palmerton. In 1983, the site was designated as a Superfund site, and placed under the jurisdiction of the U.S. Environmental Protection Agency. The company who owned the zinc company was made responsible for paying to repair the ecological damage. That company was at the time, Viacom International, now called CBS Operations (as in the TV station).

LGNC developed a remediation plan whereby we would plant warm-season grasses on the barren areas. Grasslands are in short supply in eastern North America, where there once were many small grasslands because of beaver activity and burning by Native Americans. CBS and EPA went along with the plan. In 2003, we planted 56 one-acre test plots. In 2006, after thorough evaluation of the growth of the grasses, EPA consented and the remaining barren areas were planted.

The various test plots were testing 6 different kinds of compost for effectiveness. The protocol below was used to evaluate the results of our experiment, in which we planted 4 different plots of each kind of planting (these duplicate plots are called replicates in the scientific method.) When the protocol was performed, all 4 replicates were averaged together to evaluate their performance.

EPA set up performance standards to evaluate the success of the remediation efforts, and environmental engineers devised a method for measuring the success of the grass plantings.

Total Cover Analysis Protocol

The actual total cover analysis protocol involved setting up a board with 20 holes on a pair of tripods. A laser pointer was turned on and inserted into each hole in the board such that the laser beam pointed toward the ground. The board was set up at three randomly selected plots in each test plot, and the engineers carried out the protocol. For each of the 20 lasers, they observed what the beam hit first and recorded that with a check mark on the data sheet. They later used this information gathered in the field to calculate the % cover and to determine if the performance standard was met.

In this simulation, ideally, you will work in teams of 4 to perform the total cover analysis. Randomly select a point to start do your first trail in your “test plot”, then the other two points will be at the points of an equilateral triangle that is approximately 10 meters on a side. Starting at the first point, two team members stretch the rope that simulates the board and lasers, so that the knots simulate the spots where the laser beams would have first touched something. A third team member should “read” the data of the knots to the fourth team member, the recorder. (If there are 3 members of a group, then the data "reader" must also record the results.) The reader must tell the recorder the number of the knot and whatever it touches first on the way to the ground. The choices are: Standing grass (dead or alive, since it was alive last fall), plant litter (dead grass, dead leaves, dead plants, but not wood, since the dead wood is very old), compost (from the applications last year), wood (dead for 50 or more years but did not decompose), Rock <2" or soil (bare ground or pebbles/stones up to 2 inches long), and Rock >2" (including boulders)

As the "reader" reads the information (point 1 - standing grass; point 2 – rock >2", etc.) the recorder check the appropriate box on the data sheet. The group then moves to the next point and records a second set of checkmarks on the next section of the data sheet. Repeat this at the third point. You should have 3 sets of 20 check marks when finished.

Analysis

After you complete the measurements (upon returning to the education center), count the number of checkmarks under each column for each group of 20. Then add up the 60 checkmarks and place those numbers on the data sheet. Finally, do the calculations to determine the % cover of each of the 6 types of cover, and of the combinations listed. Record the results.

Evaluation of the procedure (questions to consider)

EPA has set the performance standard at 70%. Since it is unrealistic to expect grass to grow on a rock, EPA allows CBS to count checkmarks with standing grass and rocks greater than 2" in size as "covered."

1) Why did the EPA require 4 test plots of each kind – why are replicates necessary?
2) Why did you average the tests 3 different places in your test plot?
3) Did your test plot meet the standard with standing grass only?
4) Did it meet the standard with grass and rocks > 2"?
5) Based on your observations of the grassland restoration area and the results of your test plot, would you say the grassland in general is a) meeting the standard, b) exceeding the standards, or c) below the standard?
6) Should CBS be allowed to count large piece of wood the way they do rocks > 2"? Why or why not?
7) Do you think this is a good method to evaluate the % cover (why/why not)?
8) Does this work qualify as science? Why or why not?

Data Sheets

Test Plot #	Grass	Plant litter	Compost	Wood	Rock <2"	Rock >2"
	(standing)				or soil	
Point 1						
Point 2						
Point 3						
Point 4						
Point 5						
Point 6						
Point 7						
Point 8						
Point 9						
Point 10						
Point 11						
Point 12						
Point 13						
Point 14						
Point 15						
Point 16						
Point 17						
Point 18						
Point 19						
Point 20						
Total checks						

Test Plot #	Grass	Plant litter	Compost	Wood	Rock <2"	Rock >2"
	(standing)				or soil	
Point 1						
Point 2						
Point 3						
Point 4						
Point 5						
Point 6						
Point 7						
Point 8						
Point 9						
Point 10						
Point 11						
Point 12						
Point 13						
Point 14						
Point 15						
Point 16						
Point 17						
Point 18						

Point 19						
Point 20						
Total checks						
Test Plot #	**Grass**	**Plant litter**	**Compost**	**Wood**	**Rock <2"**	**Rock >2"**
	(standing)				**or soil**	
Point 1						
Point 2						
Point 3						
Point 4						
Point 5						
Point 6						
Point 7						
Point 8						
Point 9						
Point 10						
Point 11						
Point 12						
Point 13						
Point 14						
Point 15						
Point 16						
Point 17						
Point 18						
Point 19						
Point 20						
Total checks						
Total checks						
for 3 tests						
Calculations					**% Cover**	
Formula: # of checkmarks on three trials/60 X 100 = % cover						
Test plot#						
Total cover standing grass						
Total cover plant litter						
Total cover compost						
Total cover wood						
Total cover soil/rocks <2"						
Total cover rocks > 2"						
Total cover standing grass and rock > 2"						

Total cover standing grass, rock>2", and wood			
Total cover standing grass, grass litter, rock > 2", and wood			

Appendix I

Food Webs and Ecosystem Restoration

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Summary

With increasing human impact on natural ecosystems, there needs to be greater attention to the processes of ecosystem restoration. In addition to restoring plant cover and an appropriate mix of species, it is also necessary to restore ecosystem function. An important measure of ecosystem structure and function is the food web which represents the linkages between the organisms that make up a particular ecosystem. Food webs have been an important element of ecological investigation for many years. However, only recently has theoretical understanding of food webs advanced to a level that it can generate testable hypotheses about ecosystem function. We propose to take advantage of a unique opportunity to study the reassembly of a terrestrial food web during the restoration of a severely degraded ecosystem in northeast Pennsylvania. This will enable us to develop criteria which can be used to evaluate restored ecosystems and thereby determine to what extent they have achieved the functionality of existing natural ecosystems. We hope to take advantage of new developments in the theory of food webs in proposing these criteria. If we are successful, we will have helped to bridge the gap that lies between academic conservation biology and conservation practice.

Project Description

Inspired by the writings of Robert McArthur (1955) and Eugene Odum (1969), ecologists in the 1960's and early 1970's tended to believe that an increase in the number of species promoted ecosystem stability. This belief was challenged by Robert May (1973a, 1973b) who showed that there was no *a priori* reason to expect that increasing diversity in models of natural ecosystems was associated with increasing stability of those models. Since many natural ecosystems possess observably stable characteristics, this discrepancy has prompted a search for those characteristics of natural ecosystems that promote stability.

In a recent paper, Neutel et al. (2007) examined the stability of belowground food webs occurring along a successional gradient at two dune sites in the Netherlands. They found that food web complexity increased with successional age. Stability did not increase monotonically with ecosystem age. Instead, Neutel et al. (2007) suggest that stability follows an alternating pattern; as biomass builds up top predators become more abundant which tends to increase stability. When a new predator appears, this tends to decrease predation pressure on the underlying trophic levels and thereby lower stability.

Both the results of Neutel et al. (2007) and Rooney et al. (2006) highlight the importance of predation or so-called top-down control in regulating ecosystem function and promoting stability. It is therefore reasonable to expect that a successful ecosystem restoration will include increasing participation of predators and omnivores in the food web. The project proposed here will document the food webs on both heavily disturbed and undisturbed sites at the Lehigh Gap Wildlife Refuge in eastern Pennsylvania with a view towards testing this hypothesis.

Lehigh Gap Wildlife Refuge

The Lehigh Gap Wildlife Refuge consists of 750 acres located in the Lehigh gap area of the Kittatinny Ridge (Blue Mountain) in Lehigh and carbon counties of Eastern Pennsylvania. Lehigh River flows through Lehigh gap. In 1898, two large zinc smelting plants were constructed by the New Jersey Zinc Company and the town of Palmerton was established to house the plants' employees. The zinc smelter operated for more than 80 years, employing many people. During this period the forests of Kittatinny Ridge downwind from the smelter were destroyed by emissions of sulfur dioxide and the heavy metals zinc, cadmium, and lead. As a result vegetation and microbial life were eliminated on the mountainside south of the Lehigh River. The elimination of vegetation led to the erosion of an estimated 12 to 24 inches of topsoil from the sides of the mountain, leaving rocks, mineral soil, and dead trees.

In 2002 a non-profit group, the Lehigh Gap Wildlife Center, purchased 750 acres on Kittatinny Ridge and became involved in the revegetation effort. Following conversations with representatives of the Delaware and Lehigh National Heritage Corridor and US Department of Agriculture, they decided to try to establish warm season grasses to avoid some of the problems encountered by earlier revegetation efforts.

Warm season grasses are generally considered to be native to the prairies of the Midwest and eastern Great Plains, but they are also found in eastern Pennsylvania. In the normal course of succession they are overtopped and replaced by trees. For revegetating the Lehigh Gap site, warm season grasses possess a number of advantages including: 1) they are native to Pennsylvania, 2) they grow in poor soil conditions and are tolerant of heavy metals and 3) they have deep root systems. Warm season grasses grow quite tall and provide habitat to birds and small mammals. After several years warm season grasses are expected to build up the soil organic matter through death of the root systems and the accumulation of dead grass on the surface. Eventually temperate forests are expected to replace the grasses once the organic matter in the soil has been reestablished, unless management of the ecosystem with controlled burns arrests succession and maintains the grassland.

In 2003, test plots were established on the lower mountain while steep slopes were hand-seeded (Hoopes 2007). A successful trial of aerial seeding was conducted in 2004. In 2006 full-scale replanting was carried out using crop dusters and manure spreaders pulled by heavy tractors. By July of 2006 all of the contaminated areas were planted with warm season grasses. In the summer of 2007, one year after planting, establishment was successful in most of the contaminated area.

Stable isotopes and food webs

Almost all of the grasses planted possess the C_4 photosynthetic pathway. The C_4 pathway differs from the more commonly encountered C_3 pathway biochemically and physiologically. It permits higher rates of photosynthesis while conserving water and is often found in plants in warmer climates. The C_3 pathway, also known as the Calvin cycle, discriminates against carbon dioxide containing the stable isotope carbon 13. About 1% of carbon dioxide in the atmosphere contains carbon 13, while the rest is carbon 12. Consequently C_3 plants have a lower proportion of carbon 13 in their tissue than is found in the atmosphere. In contrast the C_4 photosynthetic pathway does not discriminate strongly against carbon 13 (O'Leary 1993). The result is that C_3 plants and C_4 plants have differing ratios of carbon 13 to carbon 12 in their tissues. Using a mass spectrometer, the isotope ratio can be easily determined for a small sample (5 mg) of plant material.

When an herbivore consumes a plant with a given photosynthetic pathway, the ratio of carbon 13 to carbon 12 in the tissue of the herbivore reflects the carbon isotope ratio of the plant. As a result, an insect which consumes a C_3 plant will have less carbon 13 than an insect which consumes a C_4 plant. Similarly, individuals whose diet is based mostly on corn (C_4) will have a lower ratio of carbon 13 to carbon 12 than individuals whose diet is based mostly on wheat. Individuals who eat a mixture of C_3 and C_4 species will have carbon isotope ratios that are intermediate between those for C_3 and C_4 plants.

Carbon isotope ratios propagate themselves through the food chain depending on what proportion of the diet is based on C_3 plants or C_4 plants. For example, in the United States the carbon isotope ratio of individuals who eat beef which has been fattened on corn will be intermediate between the carbon isotope ratios for C_3 and C_4 plants since the beef is raised on a mixture of C_3 and C_4 plants. Thus, the carbon isotope ratio provides an important clue as to which portion of the food chain and individual is using.

For the members of the food chain on the Lehigh Gap Wildlife Refuge, differences in carbon isotope ratio should reflect differences in habitat. Insects and other animals that are found mainly in the revegetating contaminated sites should have a carbon isotope ratio close to that of the C_4 grasses found in those sites. Animals that utilize the surrounding vegetation should have a carbon isotope ratio that is close to that of the C_3 plants that are characteristic of forest vegetation. Animals with intermediate carbon isotope ratios will be suspected of utilizing both the revegetating sites as well as the surrounding landscape.

Objectives of the project

The primary objective of the project is to assemble a food web for both the formerly contaminated areas of the Lehigh gap wildlife refuge as well as for the surrounding landscape. A second objective will be to analyze the food web for stability using current methods.

Methodology

The list of potential participants in the food web at Lehigh gap wildlife refuge is quite long. A list of wildlife sightings (http://www.lgnc.org/wildlife_sightings.htm) shows 14 species of mammals, 10 species of amphibians, 12 species of reptiles, and 149 species of birds. In the spring and summer of 2007 we proposed to conduct two sampling campaigns for insects, birds, and small mammals. We will conduct the sampling campaigns in the restored site and at three positions along a transect from the restored ecosystem into the native ecosystem. We will also sample plants from the restored ecosystem to determine the ratio of C_3 and C_4 species by estimating cover using standard methods. Insects will be sampled using sweep nets and Berlese funnels. For birds, we will conduct a mist-netting campaign in both the contaminated sites and in the surrounding vegetation. We will sample feathers and feces from the birds that are caught to determine the isotope ratio (Podlesak et al. 2005). Concurrent with the mist netting we will also have a trapping campaign for small mammals. We will sample feces and possibly take a small amount of tissue from the ear. Wilkes University has all of the necessary permits needed to capture small mammals and birds. For larger mammals we will initiate a search for feces, which we will try to identify according to appearance or possibly using DNA analysis.

Sampling will be carried out by teams of students from Wilkes University. In addition to the students who are directly listed as participating in the project, students from other labs will also be encouraged to participate in the sampling. Assorted insect samples will be classified to order and trophic level through the examination of mouthparts. Voucher specimens of each insect will be saved for later identification by experts. Larger carnivorous insects will be dissected and their stomach contents examined to determine which prey species they are eating. All specimens will be dried and ground in a ball mill to a fine powder and then prepared for isotope analysis by mass spectrometer. Because we will not be sampling birds and small mammals destructively we will have to rely on samples of their feathers and/or feces to determine what they are eating. If large scat samples are found by either the sampling teams or by other visitors to the site, they will be dried and used for isotope analysis.

When all the samples are prepared, they will be sent to a national lab for a determination of isotope ratios. Not only will we analyze for the ratio of carbon 13 to carbon 12 ratios, we will also assay for the ratio of the stable isotope nitrogen 15 to nitrogen 14. This ratio has been found to be an indicator of trophic position at least in lake ecosystems. Organisms that are found higher in the food chain have been observed to have higher proportions of nitrogen 15 (Cabana and Rasmussen 1994).

Project Schedule

The project will begin in May 2008 with the first sampling trip. This will last 2-3 days during which time we will sample insects, small mammals, and birds according to the protocols described above. A second trip will be scheduled for July. After processing, the samples will be sent to an analytical laboratory in September. Analyses should be completed by the end of October. Once the results of the analyses are received, we will start to assemble the food webs, which should take until early February.

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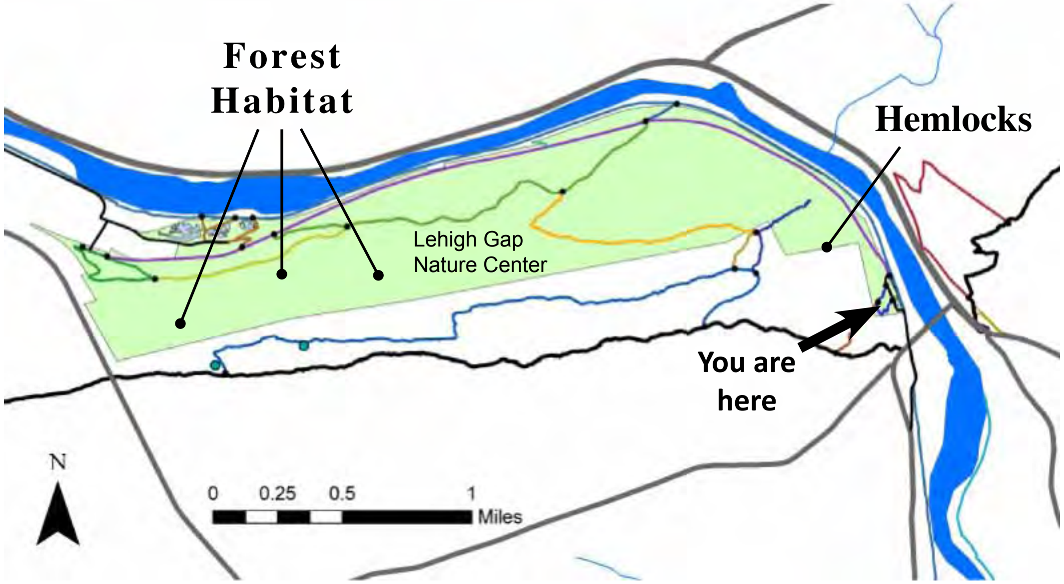
Forest

Description: Deciduous forest covers the slopes on the western end of the refuge. This forest is dominated by red oak, chestnut oak, and sweet birch. At the eastern end of the refuge is a stand of hemlocks that were once were utilized for tanning leather at the old stone building next to the Osprey House.

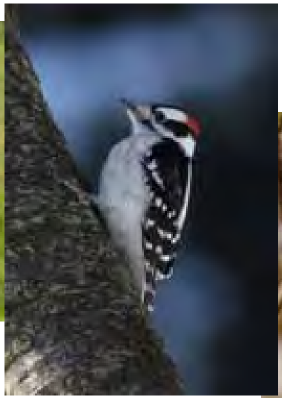
Red Oak

Sweet Birch



How to find Forest at LGNC: Forests can be seen along the GG Loop and Chestnut Oak Trail on the refuge, and along the Appalachian Trail on the south slope of the Kittatinny. These deciduous forests put on a spectacular display of autumn colors in October with the many orange sassafras trees and red tupelo (black gum) on the forest edges. There is no trail to the hemlock forest, but you can scramble up to it over the boulders behind the Osprey House. While most hemlocks in the east are dying from infestations of Hemlock Wooly Adelgids (scale insects), LGNC's hemlocks are surviving.

White-tailed Deer



Downy Woodpecker

Scarlet Tanager

Gray Fox

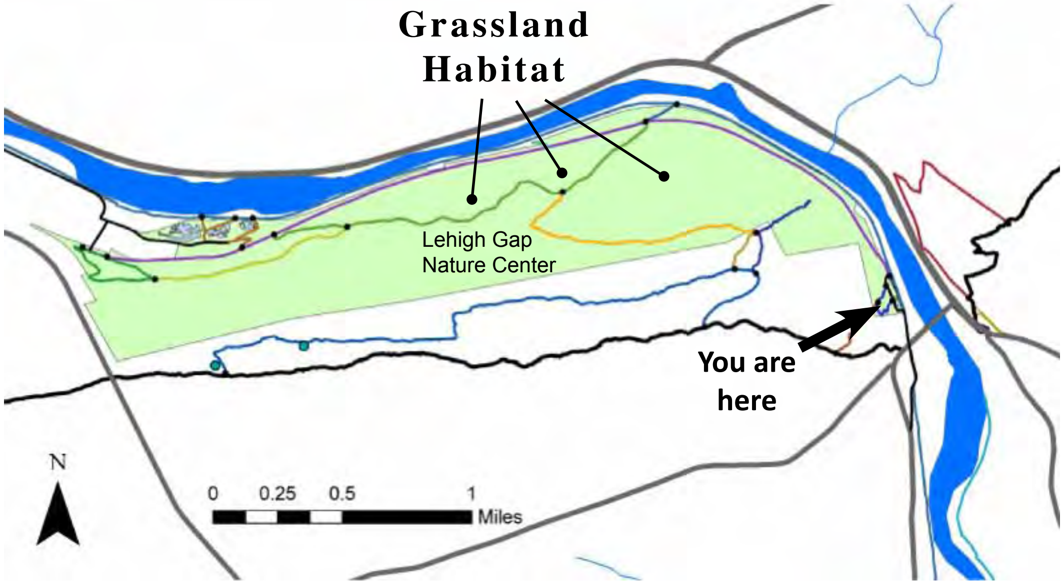
Eastern Hemlock

Grassland

Description: Tall native prairie grasses dominate this habitat type, with many spaces between the grass bunches for wildflowers. Trees will creep in and turn grassland into a young forest if allowed to grow.


Big Bluestem


Indiangrass



How to find Grassland at LGNC: At Lehigh Gap Nature Center, grassland is the result of our revegetation efforts on the formerly barren areas on the north side of the mountain. To reach this grassland area, hike from the Osprey House on the LNE Trail, which will take you directly to the grassland area. There is also a ***savanna***, grasses and scattered pitch pine trees, on top of the mountain. To reach this area, hike up the Prairie Warbler Trail, Woodpecker Trail, AT, and North Trail. The savanna is on the crest of the ridge along most of the North Trail.


American Kestrel


Spicebush Swallowtail
Common milkweed

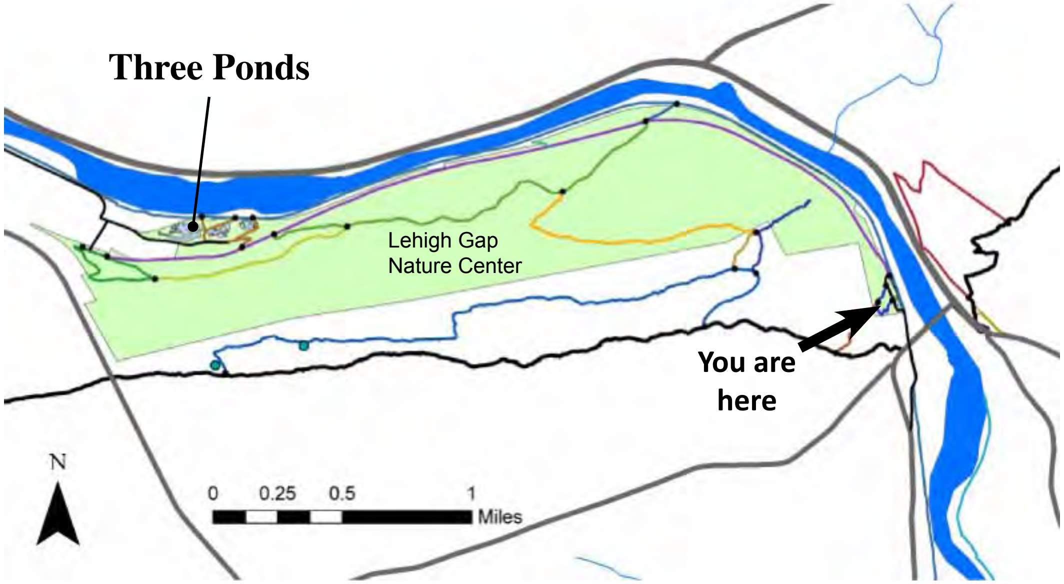

Ox-eye Sunflower

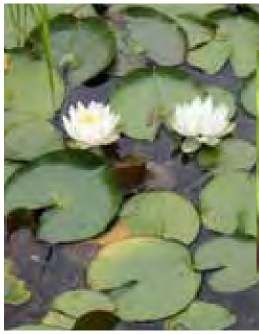

Butterfly Milkweed
Great-spangeld Fritillary


Eastern Bluebird

Ponds

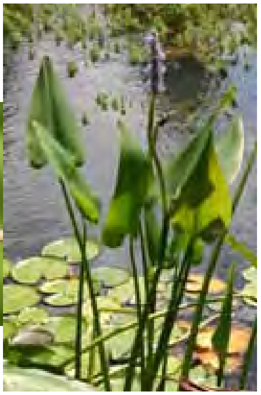
Description: Ponds are permanent bodies of standing water in which the depth of the water is shallow enough to allow the growth of plants across the entire bottom. Our ponds support fish, turtles, amphibians, and river otters, as well as bird species such as ducks and kingfishers.





Water Lillies

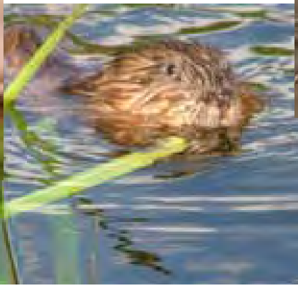
Eastern Pondhawk



Pickerelweed

How to find Ponds at LGNC: Walk out the main door of this building and turn left to find the Osprey House Pond. To reach the Three Ponds area, either hike the D&L Trail 2.5 miles to the western end of the refuge or drive to Bowmanstown and access the D&L Trail there. As you walk from the parking area there on the D&L Trail, turn right on the Three Ponds Trail to reach Mallard Pond (on your right) and Kingfisher Pond (on your left). Continuing along the D&L past the Three Ponds Trail sign, you will reach Wood Duck Pond on the right.

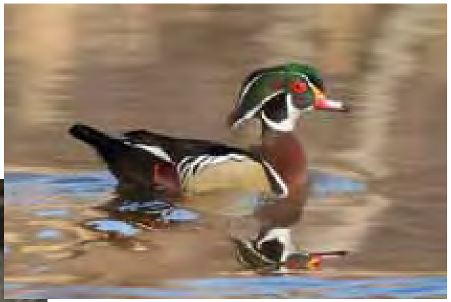
Green Heron



Muskrat

Belted Kingfisher

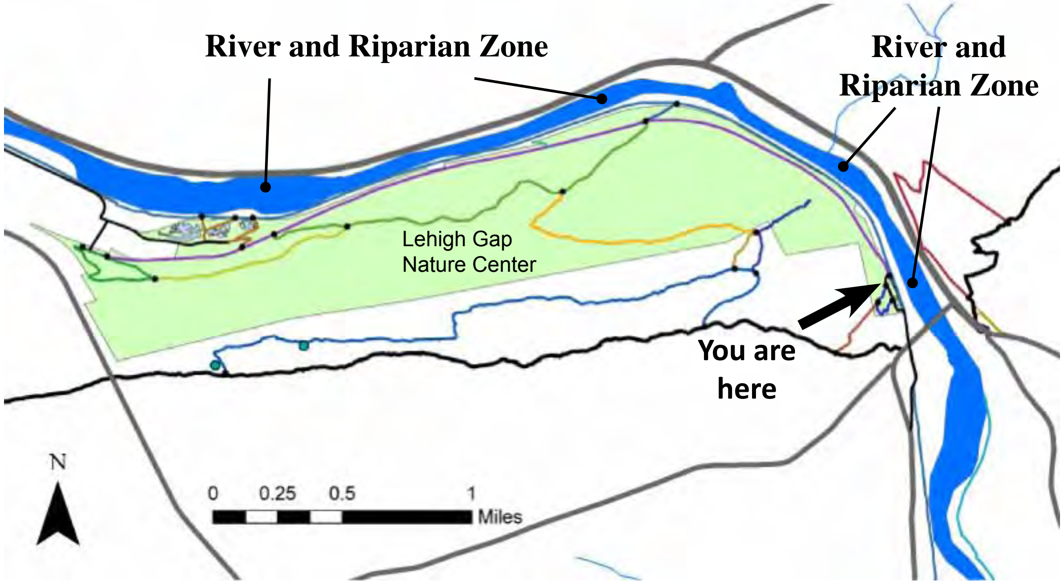
Red-spotted Newt



Wood Duck

River/Riparian Forest

Description: The Lehigh River flows for almost three miles along the refuge. It is bordered on both sides by a narrow strip of forest, and at some places a wider floodplain with few or no trees. This strip of trees or floodplain along the river is the riparian zone. Black willow and river birch are dominant trees of the riparian zone.




River Birch


Black Willow

River and Riparian Zone at LGNC: The Lehigh River can easily be accessed from the Osprey House at our boat launch or at the public boat launches just north and south of our boundaries. A walk along the D&L Trail takes you along three miles of riparian forest and flood plain. The best example of a flood plain is located at the big bend in the river where the D&L and Bobolink trails intersect.


Osprey


Bald Eagle

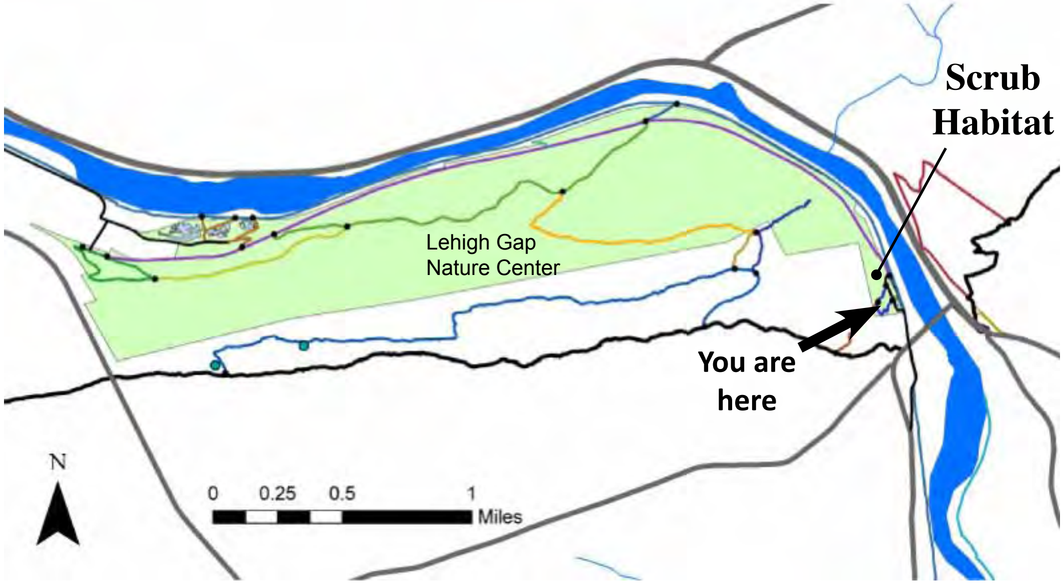

Common Merganser

Scrub

Description: Scrub, or early successional habitat, includes woody shrubs, small trees, grasses and wildflowers. It is a stage of succession as growth proceeds toward a forest habitat. We have one area managed as scrub habitat -- under the high voltage powerline uphill from the Osprey House.


Staghorn Sumac


Meadowsweet



How to find Scrub Habitat at LGNC: Scrub is easily accessible from the Osprey House parking lot. Find the trailhead for the Prairie Warbler Trail and walk the quarter mile loop through this unique habitat. We cut out the larger tree species that would eventually threaten the powerline, and we have planted several dozen plants to enhance the diversity of this habitat that supports several unique species.


Eastern Bluebird

Viceroy

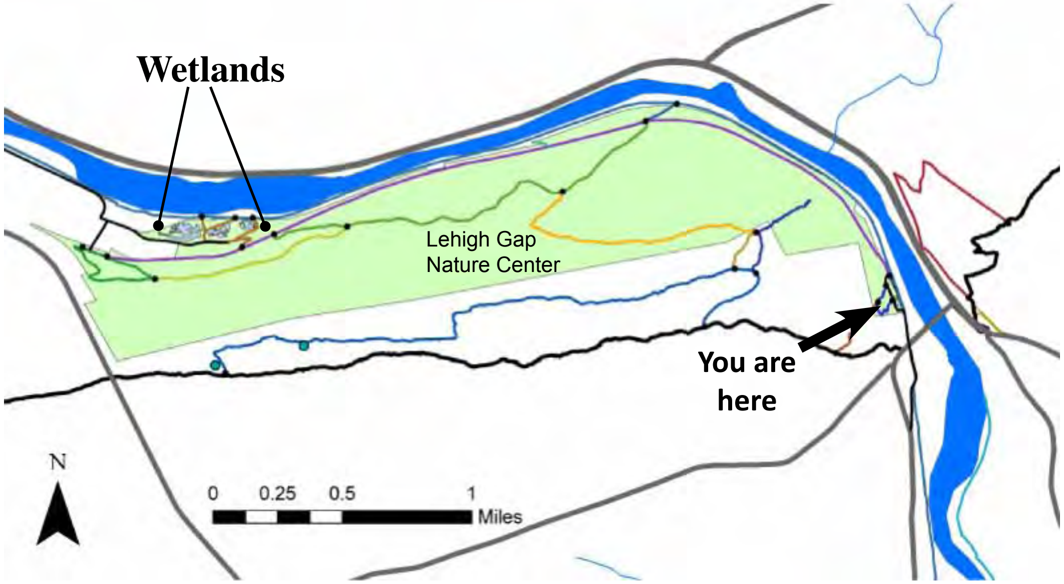

Indigo Bunting

Tiger Swallowtail


Prairie Warbler

Wetlands

Description: Wetlands are vital habitat for many species, especially amphibians which are in decline worldwide. Vernal pools (ponds that dry up during the summer), swamps (wet areas with trees), and areas around springs and seeps have soil that is often saturated with water. Buttonbush, river birch, and skunk cabbage are common plants of wetland areas.




Skunk Cabbage


Buttonbush

How to find Wetland at LGNC: Small wetland areas can be found along the floodplain of the river, but the best place to see wetlands is in the Three Ponds area. Between and around the ponds are several areas of wetland and there is a very large vernal pool and a swamp area to the west of Mallard Pond (the westernmost of the Three Ponds). Park along the D&L Trail at the Bowmanstown end of the refuge and walk the D&L and Three Ponds trails. Or hike 2.5 miles from the Osprey House along the D&L to reach the Three Ponds area.


Yellow Warbler


Spotted Turtle


Swamp Spreadwings


Pickerel Frog


Baltimore Oriole

APPENDIX K-1

Report on Lehigh University Research Activity in the Palmerton Region from 2005-2010.

Participants:
Lehigh Earth Observatory
Department of Earth and Environmental Sciences, Lehigh University
Environmental Initiative, Lehigh University

From 2005 through 2010, Lehigh faculty staff and students worked together on projects examining the legacy of industrial activity on the landscape surrounding Palmerton, Pennsylvania. This report summarizes the findings of those investigations and presents the interpretation of technical data and figures. Much of this work was supported through the EPA Brownfields Program, with additional student support from the Earth and Environmental Sciences Department, and staff support from the Lehigh Earth Observatory.

Table of Contents

Chapter 1: Background

Palmerton, PA was historically contaminated from the N.J. Zinc Company Smelter in operation from 1898 to 1980. At the peak emissions, an estimated 47 tons of cadmium, 95 tons of lead, and 3,575 tons of zinc were emitted each year (estimates of arsenic unavailable) (Water Environment Federation, 2000).

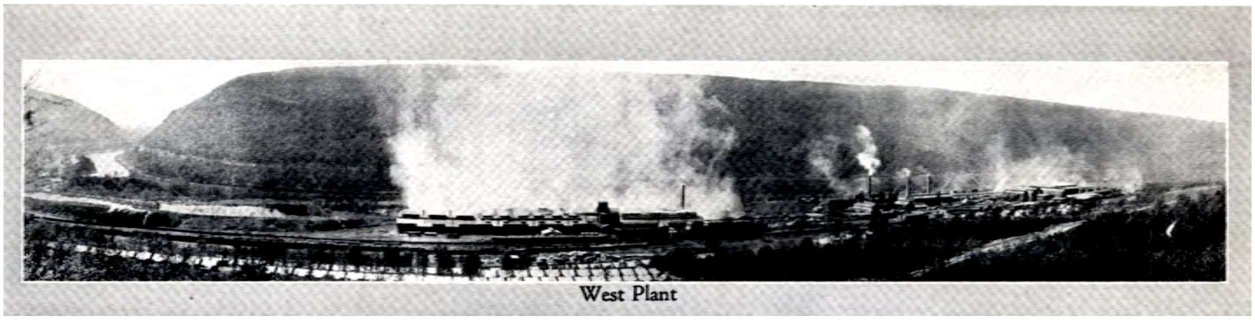


Figure 1: Undated photo of emissions from the West Plant industrial site of the N.J. Zinc Company Smelter in Palmerton, PA (New Jersey Zinc Company, 1924).

Thousands of acres were deforested on nearby Kittatinny Ridge and Blue Mountain, and high concentrations of metals in soils prevented vegetation regeneration. Lead and cadmium concentrations in soil on Blue Mountain were recorded to be over 6 times the non-residential, and over 12 times the residential standards. Zinc was almost 2 times greater than non-residential and 5 times greater than residential standards. Dead vegetation failed to decompose due to a lack of microbial activity in the soil. Lack of vegetation resulted in an estimated 1 to 2 feet of soil erosion. Aquashicola Creek and the Lehigh River were impaired by high concentrations of metals in groundwater and surface runoff; runoff from the area of the West Plant and slag pile contained metal concentrations 20 times greater than regulation standards (US EPA, 1987).

The site was placed on the U.S. Environmental Protection Agency CERCLA National Priorities List in 1983, and restoration efforts have been undertaken to re-vegetate the area and remediate metal concentrations on the landscape. While only 20% of the buildings still exist at the West Pant site, there is still a 750 meter long slag pile, and an additional 4 kilometer long cinder bank containing 32 million tons of smelting waste.

Several remediation options were considered, ranging from complete removal of contaminated soil, to monitored natural attenuation. Removal of contaminated soil on Blue Mountain carried a cost of $1.3 billion, removal of the cinder bank $2.8 billion over a project period of 29 years. Revegetation was chosen as the most viable treatment option and thousands of acres have been replanted with either native grasses or a mixture of sewage sludge, lime, fly ash, and grass and tree seeds known as Ecoloam. Ecoloam application is projected to continue into Fall 2011. Surface water has been diverted around the cinder bank, and discharge is treated before it enters Aquashicola Creek, which flows into the Lehigh River.

The Lehigh Gap Nature Center (LGNC) was established on 750 acres of the Kittatinny Ridge across the river from the West Plant. A majority of this land parcel had been contaminated by deposition of metals from emissions from the West Plant industrial site and gave the appearance of a moonscape for many years; with the restoration now trees and grasses can be seen growing across the site. Wildlife is also returning, including insects, white-tailed deer, turtles, and many species of birds (Lehigh Gap Nature Center).

Figure 2: Photos taken of a hillslope within LGNC in October 2002 and August 2006. Photo credit: LGNC.

To determine the current condition of soils and water in Palmerton, a multi-year study was conducted by Lehigh University with help from the borough of Palmerton, the Lehigh Gap Nature Center, and a grant from the EPA. Soil and water analyses were done at the West Plant, Lehigh Gap Nature Center, the Lehigh River, Pohopoco Creek, Aquashicola Creek, and up to 30 km from the West Plant.

Chapter 2: West Plant industrial site

Introduction and Methods

Soil and water samples from the former site of the West Plant were analyzed to determine concentrations of metals in the soil and the ground water at the source of the contamination. A geophysical survey was conducted prior to sampling to identify subsurface anomalies such as underground utilities or storage tanks using ground penetrating radar, metal detectors, magnetometers, and line locating equipment. An initial soil screening study was also performed to see where contaminate concentrations were the highest. Sampling sites were determined by dividing the 120 acre site into 1 acre grid areas. Shallow soil samples (to a depth of 2 ft) were collected from each grid square and were analyzed for metals, volatile organic compounds (VOCs), and polychlorinated biphenyls (PCBs) in the field using photoionization detectors, x-ray fluorescence (XRF), and PCB test kits.

A subset of additional soil samples were taken at Areas of Concern (AOCs) and Solid Waste Management Units (SWMU) following the initial soil screening to characterize subsurface fill conditions. Soil samples were taken from the surface and directly above the water table to be analyzed for metals, VOCs, semi-VOCs (SVOCs), and PCBs. Metal concentrations were compared to Pennsylvania Department of Environmental Protection (PADEP) standards (Table 1).

	Zinc	Arsenic	Cadmium	Lead
Background Levels (mg/kg)	64.7	1.5	0.29	27
Residential Standard (mg/kg)	66,000	12	47	500
Non-Residential Standard (mg/kg)	190,000	53	210	1,000

Table 1: PADEP residential and non-residential standards for soil metal concentrations

Groundwater samples were collected via grab samples, temporary wells, and monitoring wells to characterize the groundwater quality and flow at the site. Water samples were analyzed for metals, VOCs, SVOCs, and PCBs. Storm water samples were collected to assess the quality of runoff from the site. Samples were taken from storm sewers both onsite and upstream of the site.

Results

A. Soil

The data from these analyses are plotted on a map that depicts the geographic distribution of high and low concentrations (Figure 3). Zinc, cadmium, and lead concentrations in soil vary across the West Plant site: soil sampling sites with high concentration are distributed in no apparent pattern. Zinc concentrations are over the residential standards at 25 sampling locations, and samples from 39 locations exceed non-residential standards, indicating the soil is unsafe for commercial and other non-residential development in these locations. Unlike zinc, non-residential standards for cadmium in soil are exceeded at three locations localized to the eastern section of the site. All other samples are within residential standards for cadmium. Residential concentration limits for lead are exceeded in 12 samples, and 77 samples exceeded non-residential standards for lead.

Arsenic concentrations are below detection limits in all soil samples from the West Plant. It is suspected that arsenic may be present on the site, but at concentrations below the limit of what the XRF was able to detect.

The follow-up study on the AOCs shows 8 of 12 areas sampled have elevated levels of metals and 1 site contains elevated levels of VOCs.

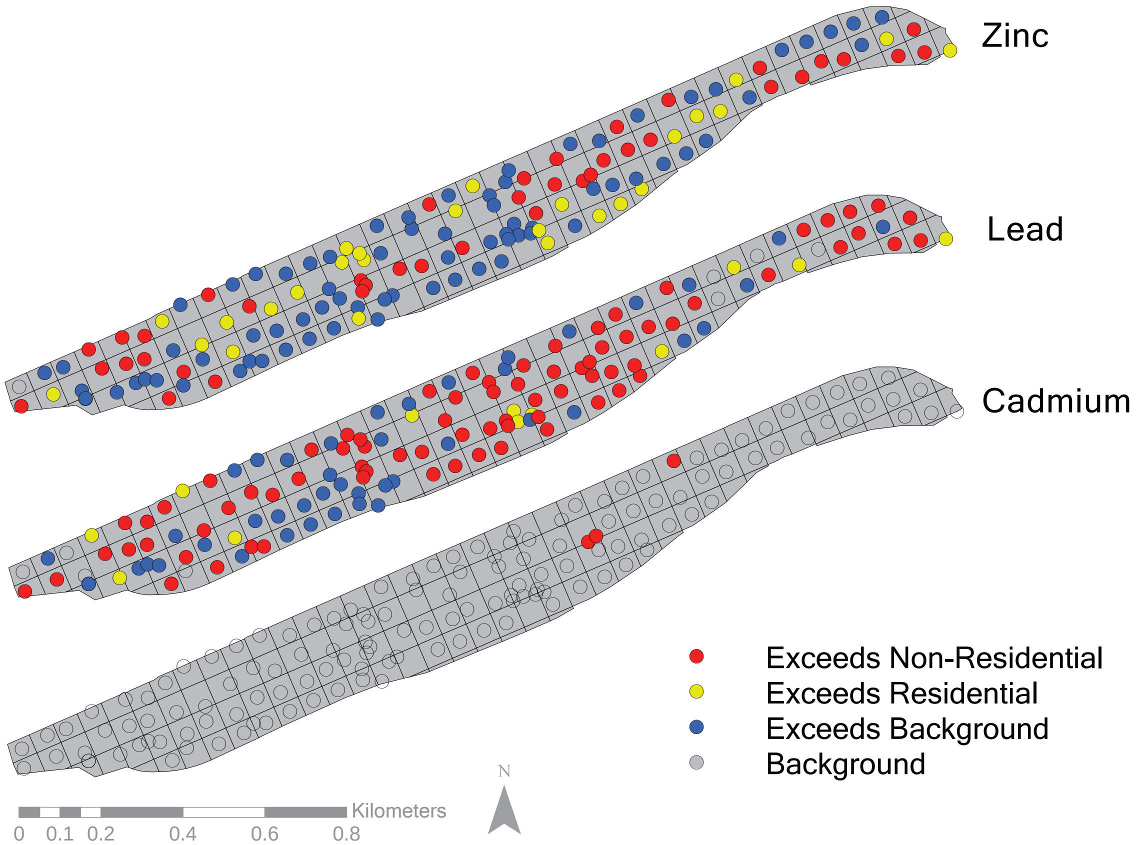


Figure 3: Zinc, cadmium, and lead concentrations in soil at the West Plant industrial site

B. Water

Samples from 10 out of 11 groundwater monitoring wells at the Wet Plant contain concentrations of metals exceeding non-residential standards. Metals found in groundwater include manganese, cadmium, mercury, arsenic, selenium, zinc, and lead. Further, 1 monitoring well contains VOCs, and 2 contain elevated levels of PCBs. The storm water samples do not contain elevated levels of metals, VOCs, or PCBs.

Discussion and Conclusion

The distribution of soil samples containing zinc, chromium, lead, and iron in soil exceeding standards show no apparent pattern. High cadmium concentrations are restricted to the eastern portion of the site, possibly a result of the proximity to the slag pile. Arsenic is not detected in soil samples. Soil samples exceed non-residential standards for zinc, cadmium, lead, chromium, and iron in multiple locations across the site. Metals are also found in groundwater in multiple locations. VOCs are measurable in one location; PCBs are measurable in two locations.

Chapter 3: Regional Soils

Introduction and Methods

Soil sampling was conducted to quantify the extent to which metals are present in the regional soil surrounding Palmerton within a 30 km radius of the West Plant industrial site (Figure 4). Sampling was focused along an east-west transect in the direction of the prevailing wind as it is the area more likely to contain metals. Sampling locations were chosen based on levels of past disturbance: sites with forests comprised of trees at least 30 years old which would have protected soil from erosion and disturbances that affect metal chemistry were preferred. Pine forests were avoided as they promote soil acidification, which may affect metal concentrations. Location relative to roads, railroads and other recent activity was also factored into selecting each site. Sampling was done on a wide a range of elevations from low valleys to high ridge tops. At each site a soil pit was dug approximately 24” in diameter and deep enough to reach the deep soil layer. Samples were taken starting with the deep soil layer to avoid distortion from the other layers. A GPS point was taken for each sampling pit in addition to a photograph and a record of the depth of each soil horizon. Samples collected were prepared by the soil digestion method and then analyzed by an Inductively Coupled Plasma-Mass Spectrometer (ICP-MS).

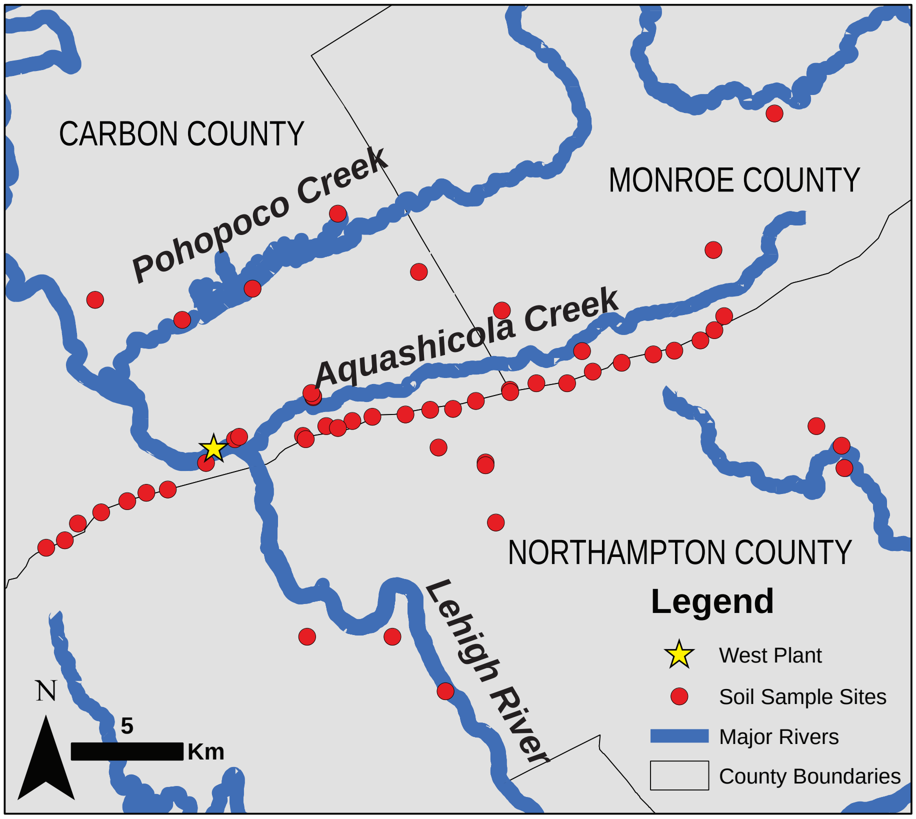


Figure 4: Regional soil sampling locations with distance from the West Plant

Results

Figure 5 shows the concentration of zinc in soil decreases with distance from the West Plant in the shallow, middle, and deep soil horizons. Zinc concentrations are significantly greater in sampling locations to the east of the West Plant. Soil samples do not contain concentrations of zinc that exceed PADEP regulatory standards for residential or non-residential soil in any layer. Zinc reaches a maximum concentration of 24,600 mg/kg in the middle soil layer and a minimum of 2.25 mg/kg in the deep soil layer.

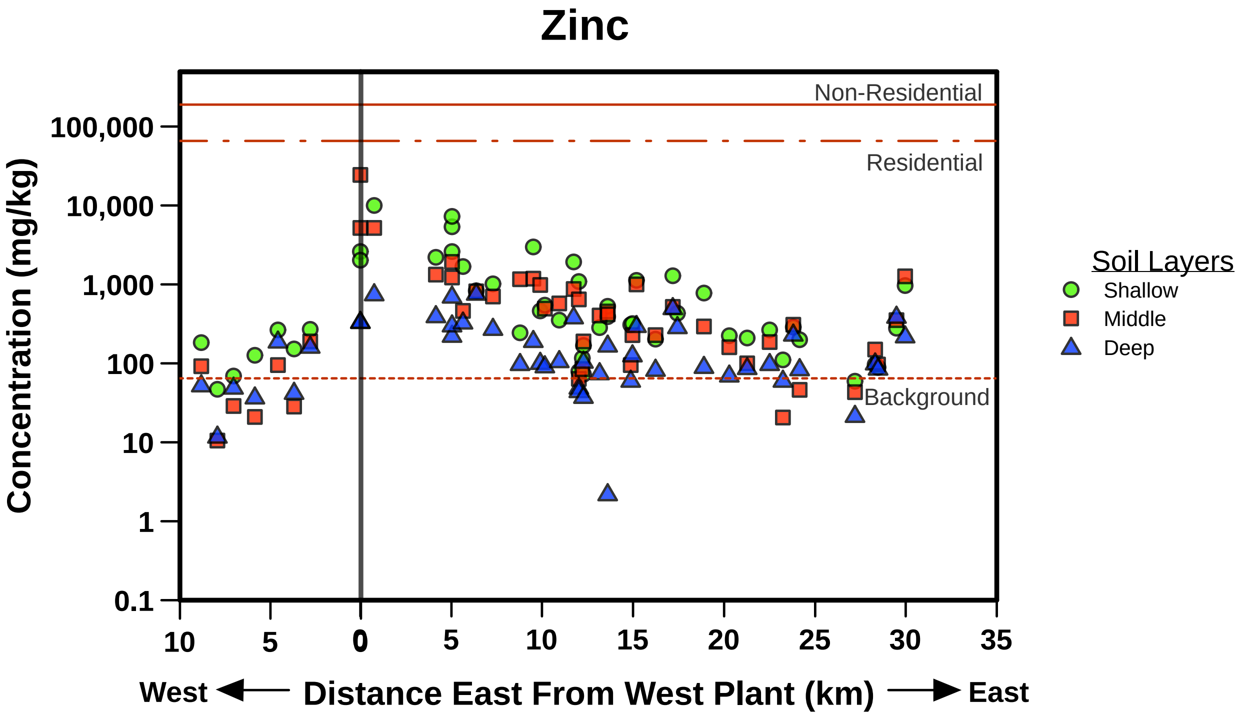


Figure 5: Zinc concentrations in shallow, middle, and deep soil layers compared to non-residential, residential, and background standards with distance from the West Plan

Cadmium concentration decreases with distance in all layers of soil in both directions from the West Plant (Figure 6). Concentrations of cadmium exceed residential soil standards in the shallow layer up to 7 km away and in middle soil up 10 km away. Cadmium concentrations exceed non-residential standards in any soil layer. Cadmium reaches a maximum concentration of 110 mg/kg in the shallow horizon and a minimum of 11.3 mg/kg in the deep horizon. Overall the concentrations of cadmium are greater to the east of the West Plant industrial site than to the west.

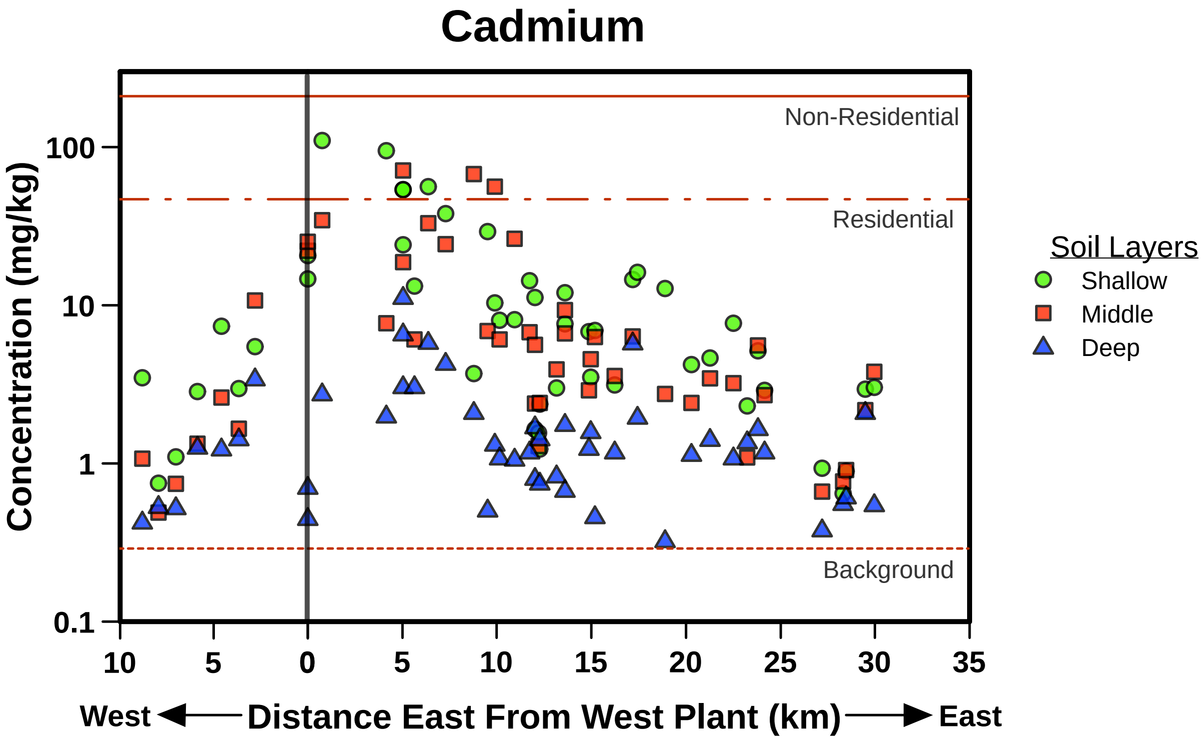


Figure 6: Cadmium concentrations in the shallow, middle, and deep soil layers compared to non-residential, residential, and background standards with distance from the West Plant

Figure 7 shows arsenic concentrations in all soil horizons do not decrease in concentration with distance from the plant in either the west or east direction. The concentrations of arsenic are higher to the east of the West Plant. Arsenic exceeds PADEP residential standards in all soil layers at locations up to 30 km from the West Plant. Concentrations of arsenic exceed non-residential standards in the shallow and middle horizons at the West Plant. Arsenic reaches a maximum concentration of 96.8 mg/kg in the middle soil layer and is unmeasurable in the shallow soil layer.

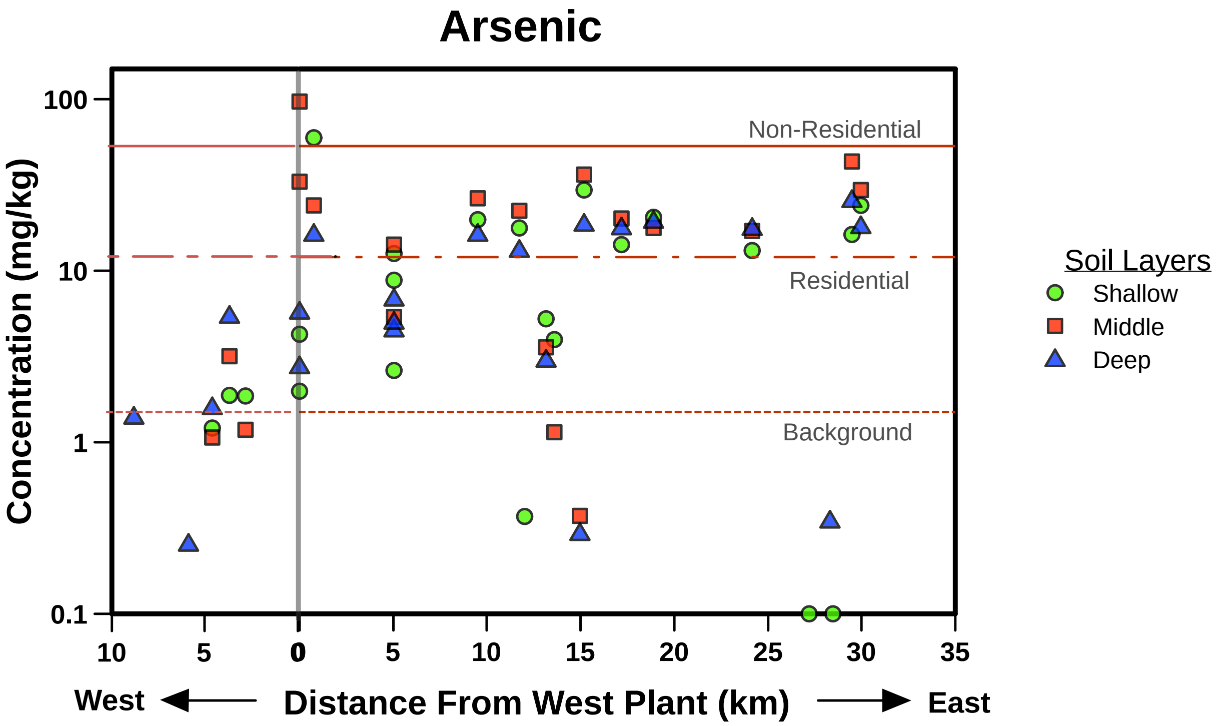


Figure 7: Arsenic concentrations in the shallow, middle, and deep soil layers compared to non-residential, residential, and background standards with distance from the West Plant

Lead concentrations are highest east of the West Plant and do not decrease with distance from the plant in either direction. Alternatively, lead remains relatively constant with respect to distance in all soil layers (Figure 8). Lead concentrations exceed residential standards in the shallow layer up to 20 km away from the zinc smelter. Non-residential concentrations for lead do not exceed PADEP standards in any soil layer. The overall maximum concentration of lead is 873 mg/kg in the shallow horizon and the minimum concentration is 1.29 mg/kg found in the deep horizon.

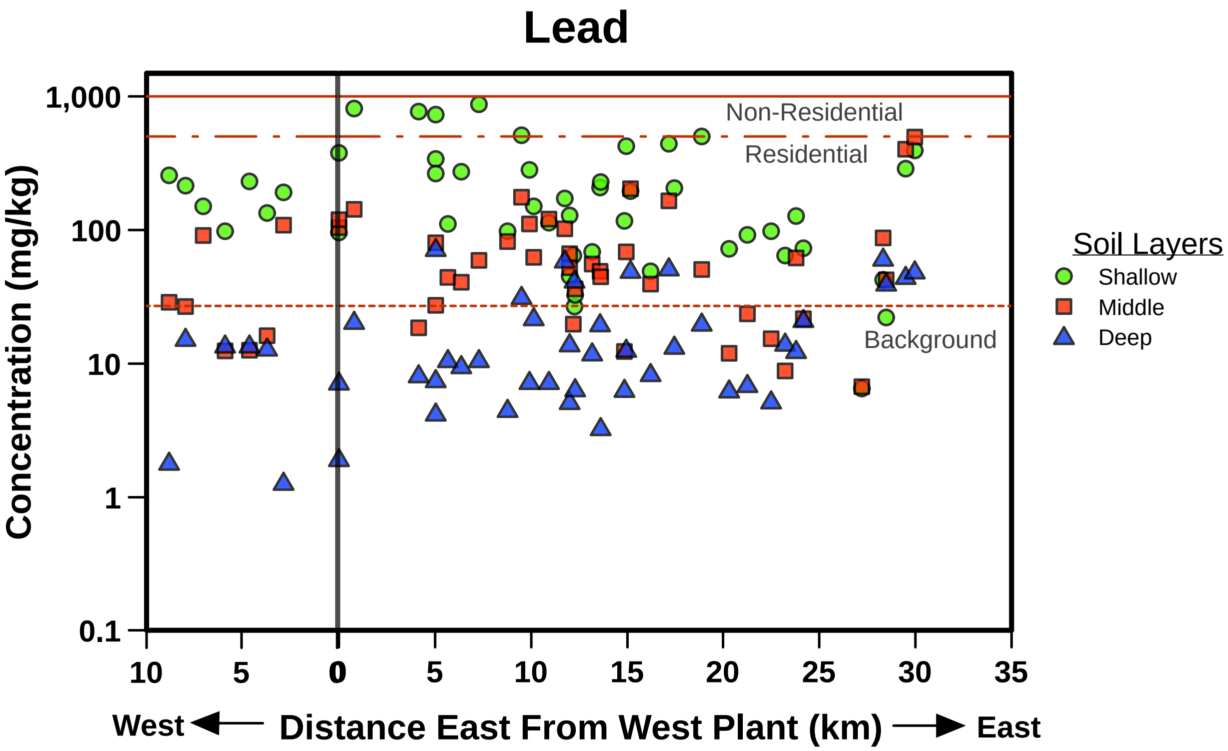


Figure 8: Lead concentrations in the shallow, middle, and deep soil layers compared to non-residential, residential, and background standards with distance from the West Plant

Figure 9 shows zinc concentrations at ridge top locations in all the soil horizons decreased with distance from the West Plant. This decreasing pattern is also seen in zinc concentrations sampled from valley sites. The same is true for cadmium (Figure 10): there is a clear negative correlation between distance from the West Plant and the concentration of cadmium for both ridge top and valley sampling locations.

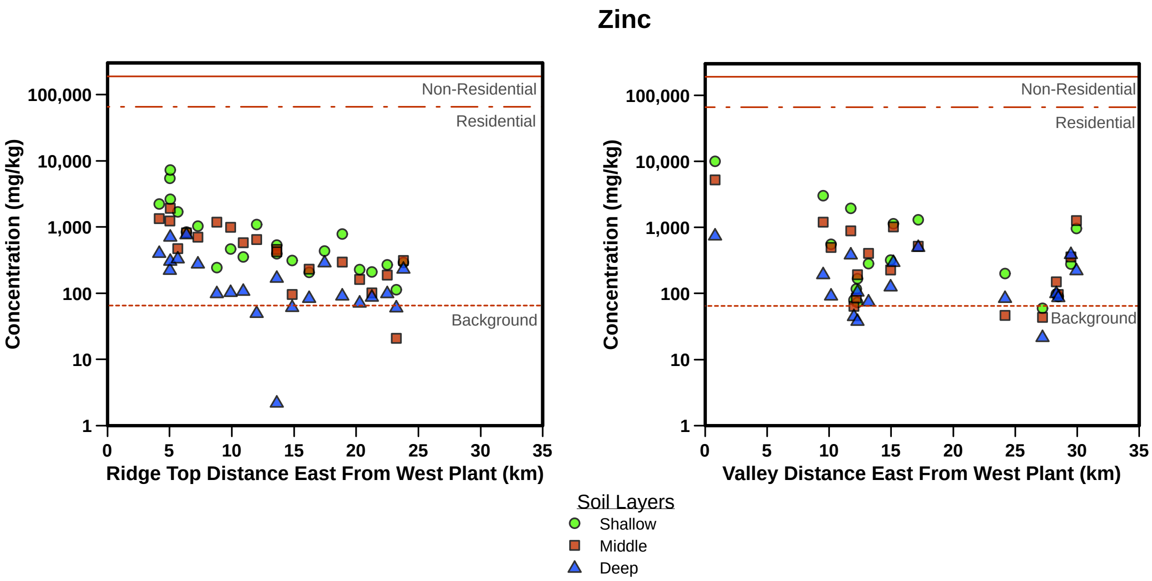


Figure 9: Zinc concentrations in the shallow, middle, and deep soil layers for ridge top and valley sampling locations compared to non-residential, residential, and background standards

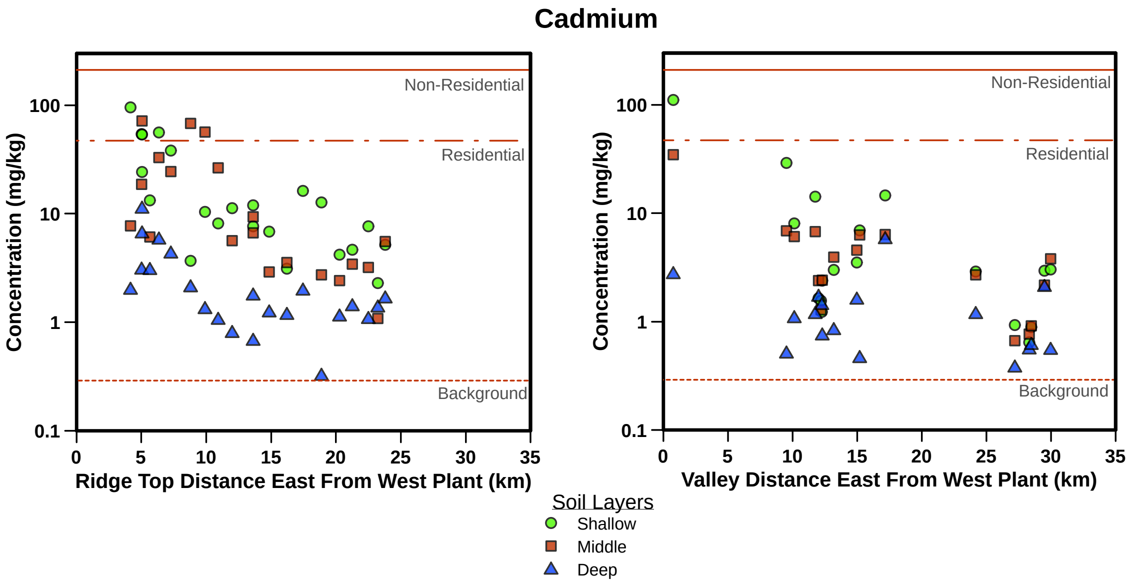


Figure 10: Cadmium concentrations in shallow, middle, and deep soil layers for ridge top and valley sampling locations compared to non-residential, residential, and background standards

Figure 11 shows lead concentrations in shallow soil for ridge top locations decreased distance from the West Plant while concentrations in the middle and deep layers for ridge top soil remain relatively constant. There is no pattern between lead concentration and distance from the West Plant industrial site in any soil horizons for the valley sampling locations. There is no apparent correlation for arsenic concentration in any soil layer for either ridge top or valley sampling locations (Figure 12).

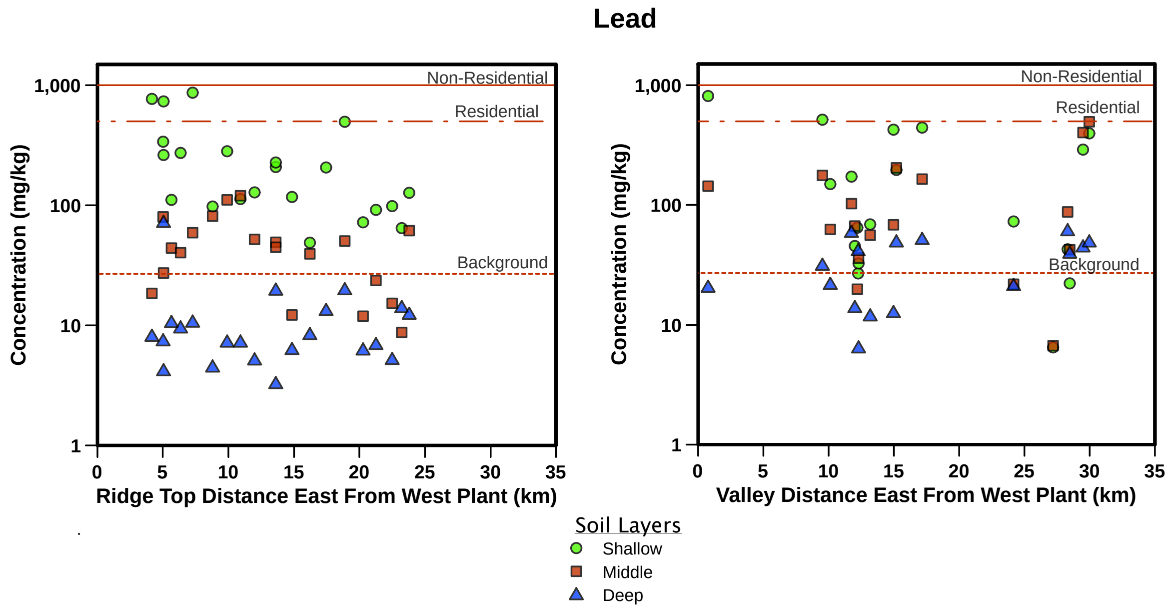


Figure 11: Lead concentrations in shallow, middle, and deep soil layers for ridge top and valley sampling locations compared to non-residential, residential, and background standards

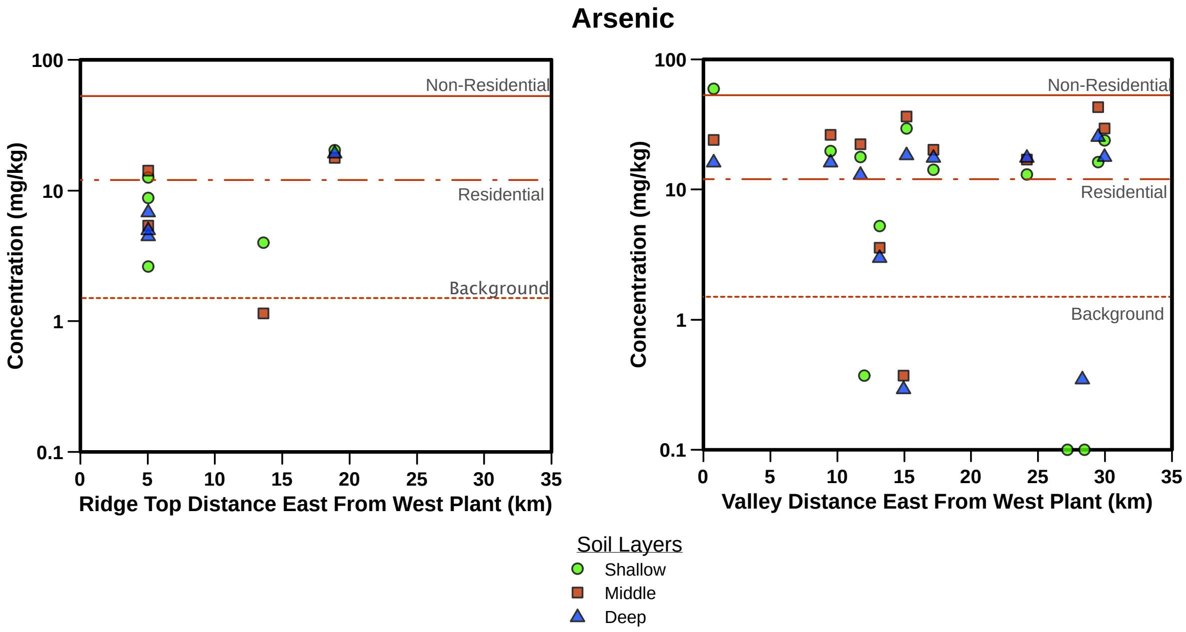


Figure 12: Arsenic concentrations in shallow, middle, and deep soil layers for ridge top and valley sampling locations compared to non-residential, residential, and background standards

Discussion and Conclusions

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. Zinc uptake by plants and its prevalence in surface soil makes it more susceptible to entering the ecosystem via food chains. The decreasing concentrations of zinc and cadmium with distance from the West Plant indicate the presence of these metals in the soil is due primarily to emissions from the West Plant. This is furthered by evidence that metal concentrations to the east of the West Plant are higher than to the west which is consistent with the prevailing wind in that area. Conversely, arsenic and lead concentrations do not decrease with distance from the West Plant, suggesting other sources may have contributed to the levels of arsenic and lead within the sampling area

These relationships are further supported by the correlations between metal concentrations at ridge top and valley locations. The negative relationship formed between distance and concentration of zinc and cadmium at both ridge top and valley locations indicates this relationship is a function of distance from the West Plant and not differences in elevation.

Chapter 3: Regional Waterways

Introduction and Methods

Surface water and groundwater surrounding the West Plant industrial site was analyzed to determine the fluxes and transport mechanisms of metal contaminants including zinc, lead, cadmium, chromium, and arsenic. The relative water volume entering the fluvial system, contaminant transport mechanism, and affect of discharge, and the source of contaminants were determined to assess metal transport.

A 14.7 km stretch of the Lehigh River between Lehighton and Walnutport, PA, running directly past the West Plant, was analyzed for metals. The main tributaries of the Lehigh River in this study site are Pohopoco and Aquashicola Creek (Figure 13). Water sampling was done between May 2009 and November 2009. Groundwater samples were collected at monitoring wells, and surface water samples were gathered from the two tributaries and the main river channel. Samples were analyzed for metal concentrations, pH, alkalinity, conductivity, and temperature. Hydrographs (discharge vs. time) were made with data from gauging stations along the Lehigh River and two tributaries (Pohopoco and Aquashicola Creek) to calculate the flux: the rate of contaminant discharge over time.

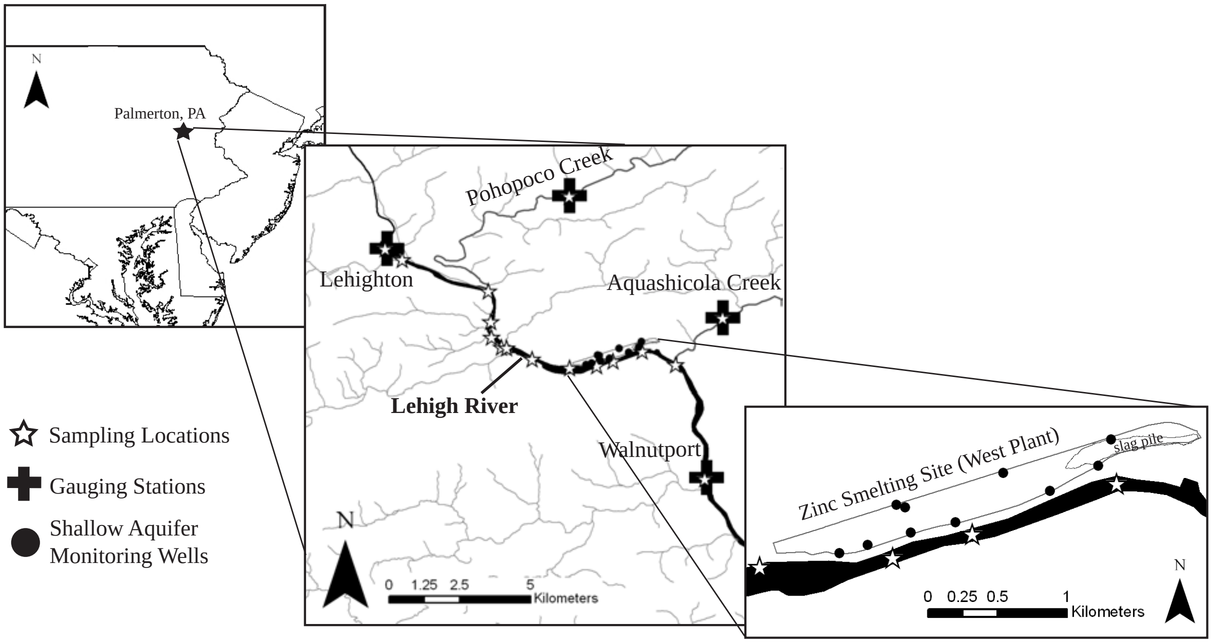


Figure 13: Site map of the project area near Palmerton, PA

Results

Figure 14 shows the estimated relative inputs of surface water and groundwater. Groundwater combined with minor tributaries accounts for 14% to 18% of the total hydrologic flux to the Lehigh River, depending on flow conditions. The major tributaries, Pohopoco and Aquashicola Creek, account for 16%, and upstream surface water inputs account for 70% of the total hydrologic fluxes. Zinc input to the Lehigh River in the dissolved phase is the largest in Aquashicola Creek, located downstream from the West Plant. Zinc in the particulate phase enters the river primarily in groundwater. Lead does not have significant sources from groundwater, Aquashicola Creek, or Pohopoco Creek compared to concentrations present from upstream sources in both the dissolved and particulate phases.

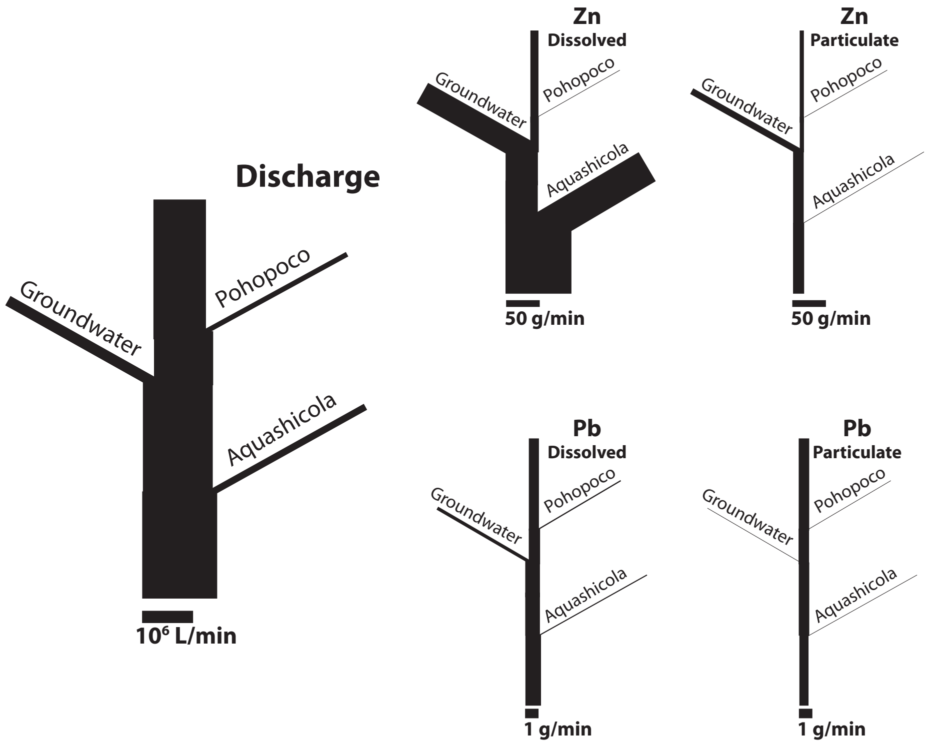


Figure 14: Conceptual diagrams showing the relative inputs of zinc and lead with discharge to the Lehigh River on a low flow sampling date

The concentration of zinc, lead, cadmium, and chromium in the Lehigh River are displayed in Figure 15. The particle sizes metals were associated with ranged between dissolved (smaller than 0.45 um), colloidal (smaller than 0.02 um), or particulate (greater than 0.45 um).

Arsenic values were below detection limits in most samples, and are therefore omitted in reported results. Concentrations of metals at each site are within US EPA Drinking Water Quality standards.

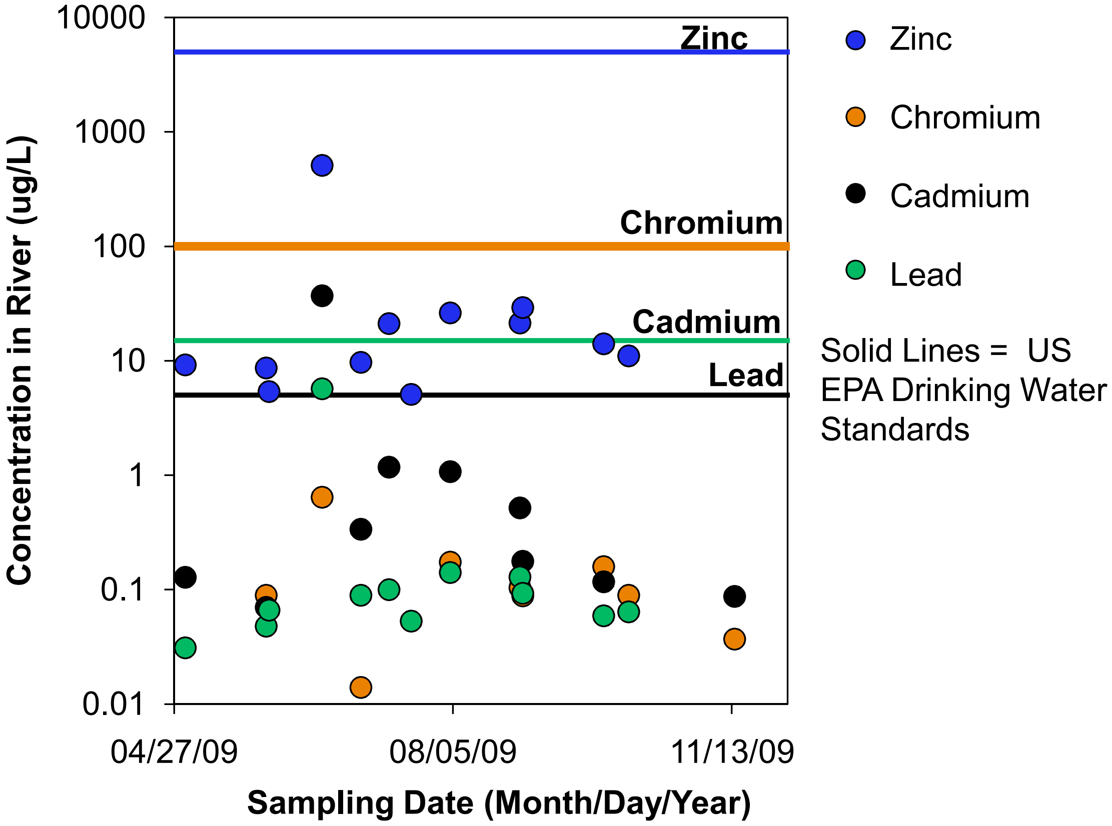


Figure 15: Concentrations of zinc, chromium, lead and cadmium in the Lehigh River during a 6 month sampling period compared to US EPA standards

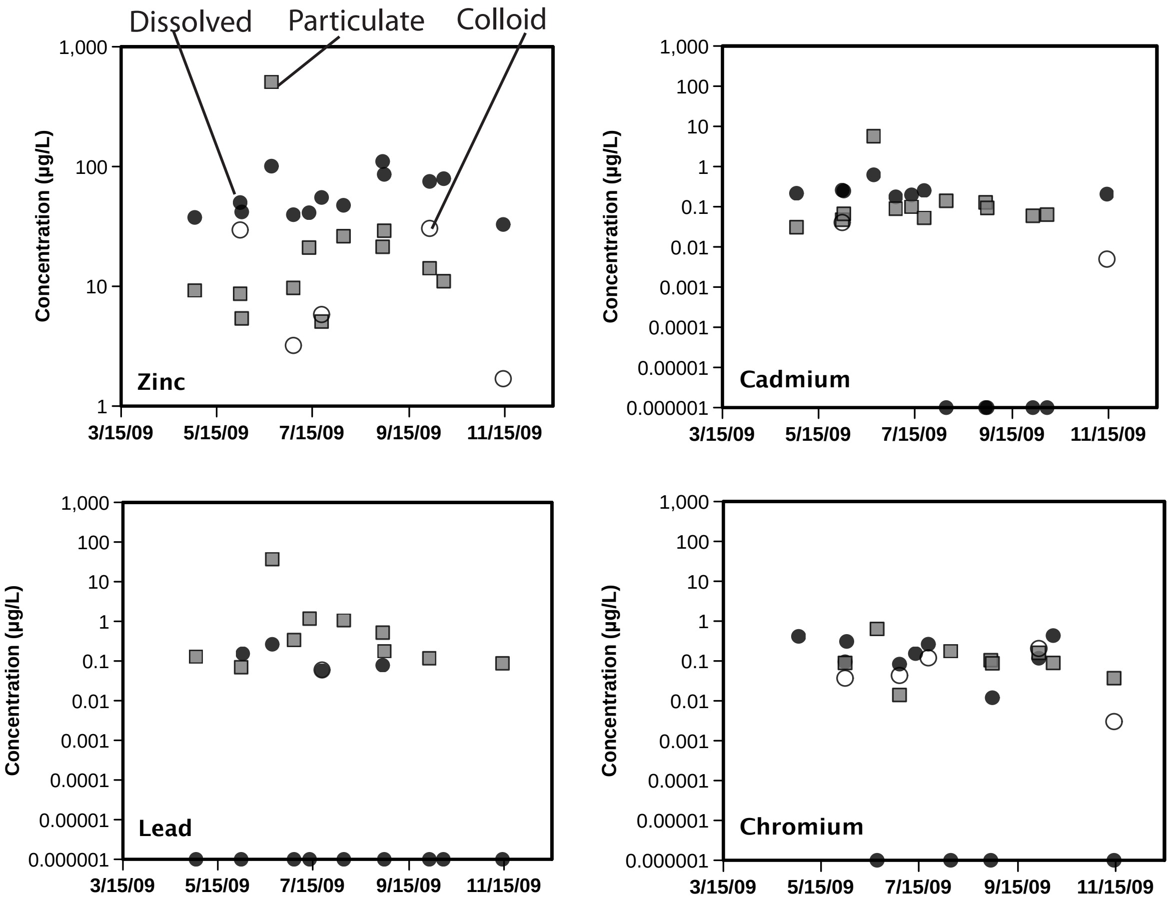


Figure 16: Concentrations of zinc, cadmium, lead, and chromium in the Lehigh River near Palmerton, PA, in dissolved (solid circles), particulate (squares), and colloid (open circles) phases

Discussion and Conclusions

Metal concentrations in the Lehigh River are within US EPA Drinking Water Quality standards. Metal additions to the river are primarily sourced in groundwater and Aquashicola Creek, located downstream from the West Plant. The lower concentrations of metals seen in Pohopoco Creek, upstream of the West Plant, compared to those seen in Aquashicola Creek indicate the West Plant may be contributing some of these contaminants to the river. The distribution of metals between each phase in the river is approximately equal, with the exception of lead which was not present in the colloidal phase.

Chapter 4: Local Soils and Streams

A. Soils

Introduction and Methods

As discussed previously, the remediation plan for the land that is now the site of the Lehigh Gap Nature Center (LGNC) was left to naturally attenuate, meaning nothing has been done to remove contaminants. This leaves the question of now thirty years after the smelter shut down, how much metal contaminants still remain in the soil? Two soil samples were collected from shallow, middle, and deep layers in soil pits dug within approximately 2 meters of Railroad, Hidden, and Smilax Springs (Figure 17). Soil samples were analyzed to determine the concentrations of zinc, cadmium, arsenic, and lead at each sampling location.

Figure 17: Lehigh Gap Nature Center with spring locations

Results

Figure 18 shows the concentrations of zinc, arsenic, cadmium, and lead in soil samples taken near each spring at shallow, middle, and deep layers within soil pits, as compared to PADEP regulation standards for non-residential and residential land, and background levels. Background levels are the concentrations of the metals that are naturally occurring. For all metals analyzed, at least one sample has metal concentrations which exceed residential standards. While this site is not intended for residential purposes, non-residential standards were also exceeded in at least one sample for each metal analyzed. The middle layer (A horizon) in soil pits contains the highest concentrations of zinc, arsenic, and cadmium, followed by the shallow (O horizon) and deep layers (B horizon). For lead, almost all samples contain higher or equal concentrations in the shallow layer over the middle and deep layers.

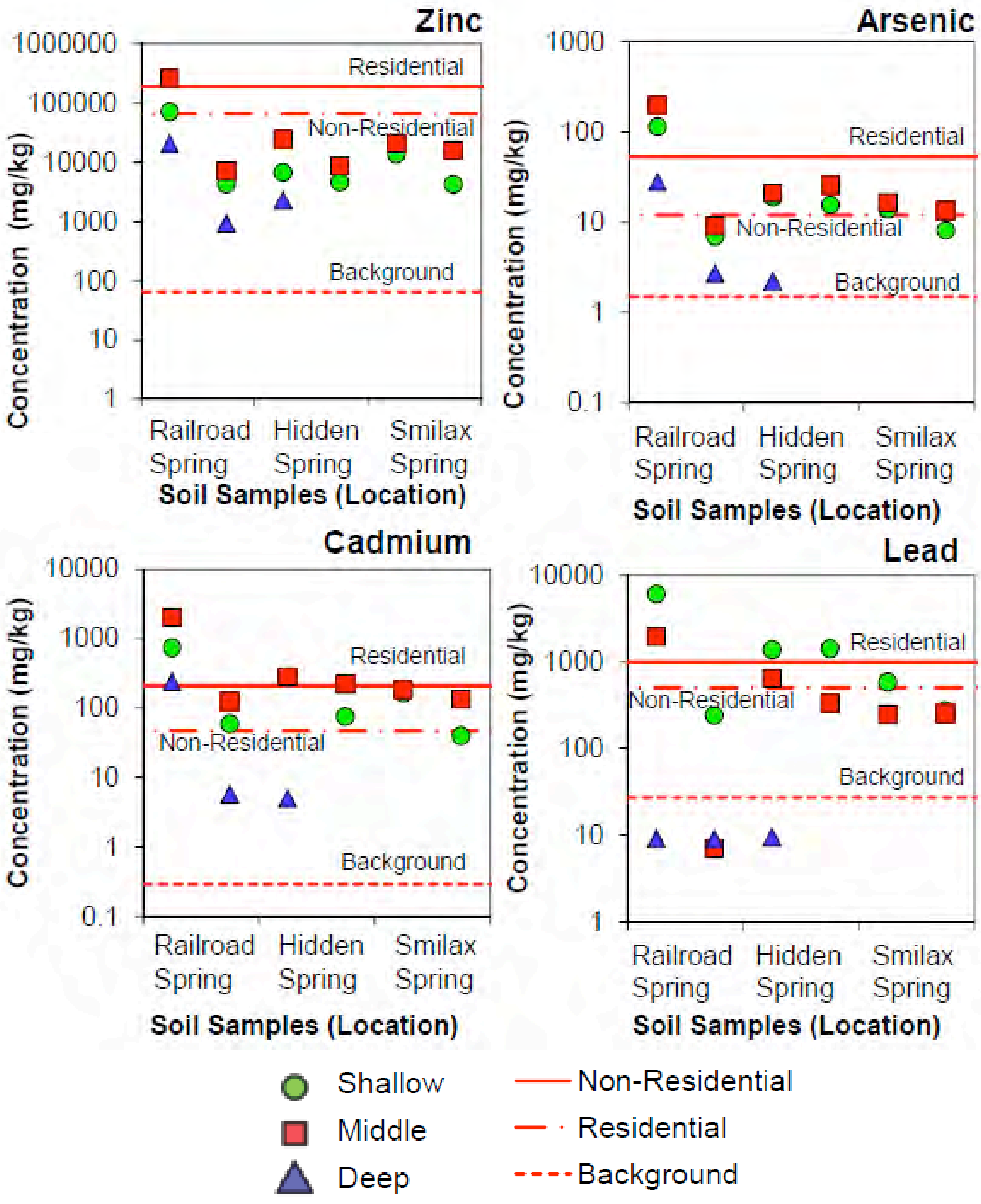


Figure 18: Zinc, arsenic, cadmium, and lead concentrations in soil samples taken near Railroad, Hidden, and Smilax Springs at shallow, middle and deep layers in soil pits, compared to non-residential, residential, and background environmental standards

Conclusion

Despite the thirty years that have passed since the West Plant industrial site closed, there are still significant concentrations of metals found in the soil at LGNC.

B. Water

Water sampling was done at LGNC to answer several questions: How much of the metals in the soil wash out in the water? Is LGNC a source of metals to the Lehigh River? We ask these questions because metal contaminants in soil can be released into the water. The ability of contaminants to adsorp (stick) to soil particles makes it possible for them to persist in soil for many years, only being released in small quantities to maintain equilibrium with changing environmental conditions (Figure 19). Environmental changes that can induce the release of contaminants from adsorped sites include precipitation, pH, oxygen availability, and competing ions (Bradl, 2004; Gambrell et al., 1980; Jensen et al., 1999; Bordas and Bourg, 2000; Abate and Masini, 2002; Bauer and Blodau, 2006; Ford et al., 2007; Wilkin et al., 2007).

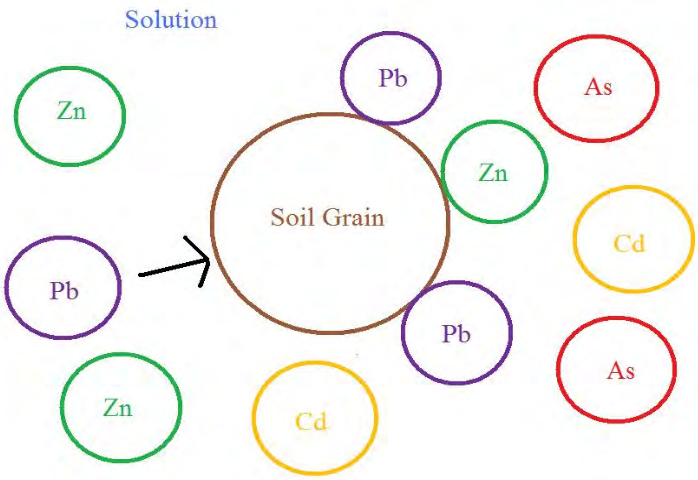


Figure 19: Illustration of contaminants adsorped to a soil grain

When it rains, the water table rises into areas of soil that were previously unsaturated. When water enters this area the ions that were adsorped to the soil grains are released in small amounts. This is similar to how a coffee maker works. The coffee grinds are like the soil; when water is added, some of the coffee flavor comes off the grinds and into the water. Add more water and more coffee comes off the grinds.

The unsaturated zone can be a source of contaminants that are only released during storm events. To see if this was the case at LGNC, we collected water samples from springs (Figure 17), along with pH and discharge data, following rain events and analyzed their elemental compositions to compare tracer elements to contaminant elements. Tracers, such as chlorine, silicon, and sodium, have similar chemical and transport properties to the contaminants and are not affected by vegetation or other biological factors, and should be evenly distributed in the saturated and unsaturated zones of soil. Fluxes of conservative tracers can be compared to metal ion fluxes to determine their source. If there is a source of contaminants in the unsaturated zone, there will be an increase in contaminant concentrations seen in spring water following storm events compared to stable contaminant concentrations. Rain water was also analyzed for metal concentrations.

Results

Following the onset of the rain event, zinc and cadmium concentrations increase compared to their pre-event values (Figure 20). Zinc concentrations in the spring reach a maximum of 119 ppb, in the rain 58 ppb. Cadmium concentrations in the spring reach a maximum of 0.3 ppb, and 0.7 ppb in the rain. Lead and sodium concentrations remain relatively constant following the rain event, while silicon and chloride concentrations show slight decreases following the peak in spring discharge. Lead concentrations reach a maximum of 0.3 ppb in the spring, and 2.7 ppb in the rain. The concentrations of arsenic are unmeasurable in all samples.

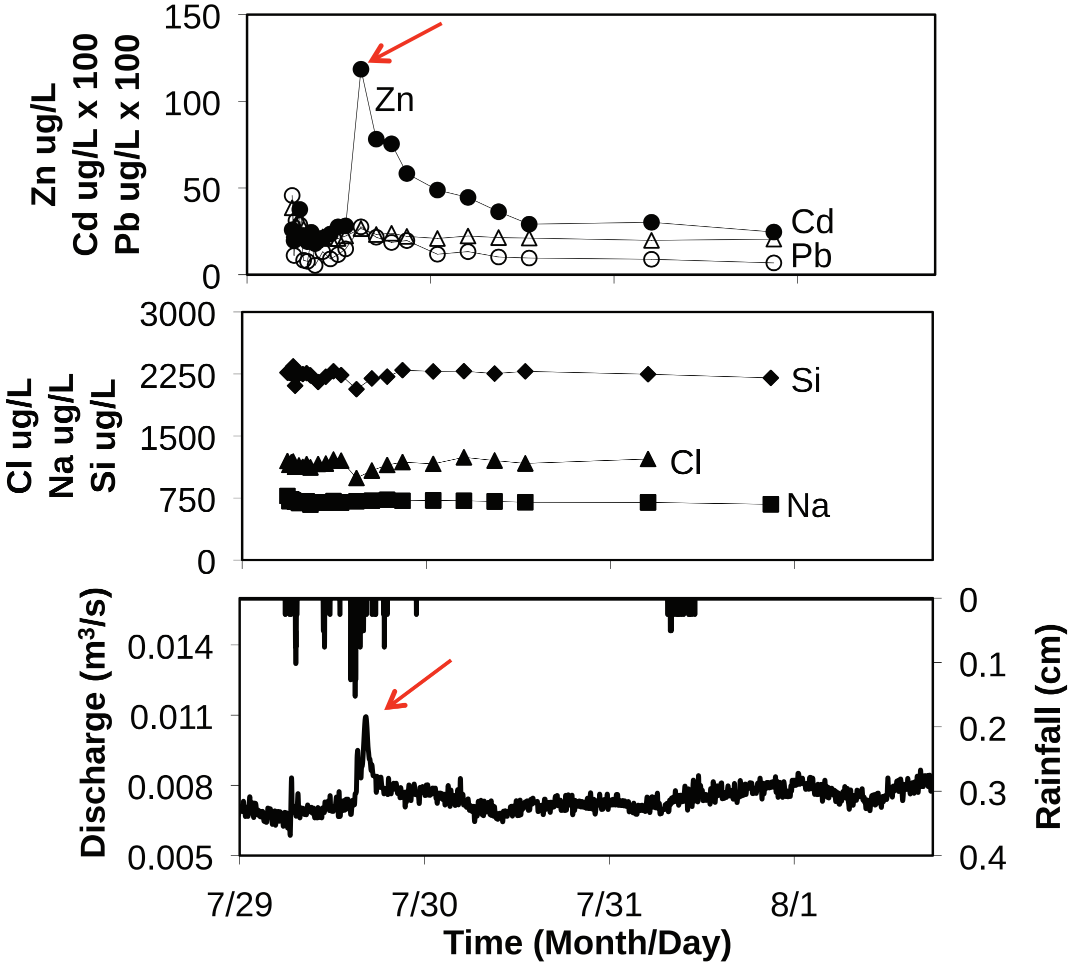


Figure 20: Concentrations of zinc (closed circles), cadmium x 100 (open circles), lead x 100 (open triangles), chloride (closed triangles), sodium (closed squares), and silicon (closed diamonds) in µg/L with precipitation and discharge for a spring at LGNC. Ion concentrations on the y-axis represent rainwater composition.

Conclusions

During rain events at spring at Lehigh Gap Nature Center, concentrations of tracers sodium, chloride, and silicon, as well as contaminant lead, remain constant, meaning they are leaking out of the soil at a steady-state, while concentrations of zinc and cadmium increase as the discharge of the spring increases. The increase in zinc and cadmium concentrations following rain events compared to the relatively stable concentrations of conservative tracers indicates these contaminants are being mobilized from adsorption sites in the soil (Figure 20). Further, the concentrations of zinc and cadmium increase corresponding with the peak in the hydrograph relative to the concentrations of the tracers, indicating the contaminants are being released from soils that are likely located in an unsaturated zone that is temporarily inundated during storm events.

The low concentrations of arsenic and lead seen in the water samples indicate that little of these contaminants remain mobile at this site. Regardless of thirty years of natural attenuation at the site, water samples indicate it still retains a significant reservoir of zinc and cadmium that is mobilized during storm events. However, the concentrations of these contaminants found in the water at LGNC are small, and concentrations of all metal contaminants are well below US EPA drinking water standards.

The low concentrations of contaminants seen in the water at LGNC 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.

Chapter 6: Future Implications for Attenuation at LGNC

Introduction and Methods

Geochemical modeling using PHREEQC Interactive 2.15.0 determined the equilibrium chemical speciation in the system. Water chemistry from spring water samples was used to model zinc adsorped to hydrous iron oxides as a function of pH and sample composition. Hydrous iron oxides serve as a representative of soil grains. Alkalinity titrations were performed to access the ability of spring water to buffer changes in pH.

Results

Water samples from LGNC contain little to no alkalinity. Zinc adsorped to hydrous iron oxides was modeled as a function of pH and sample composition from 1 sample from each spring representative of high flow conditions. The pH of the Smilax Spring sample was 6.1, the Hidden Spring sample was 5.9, and the Railroad Spring sample was 6.7. Figure 21 shows the mole fraction of Zinc adsorped to strong sites across a pH range of 5.0 to 8.0. There is a significant increase in the amount of Zinc adsorped at the Smilax and Railroad Spring samples as pH increases from 5.5 to 7.0. The mole fraction of Zinc able to adsorp to strong sites on hydrous iron oxides increases by 72% across this pH range at the Smilax Spring, and by 76% at the Railroad Spring. Conversely, for the Hidden Spring sample the mole fraction of Zinc adsorped only increases by 15% across pH 5.5 to 7.0.

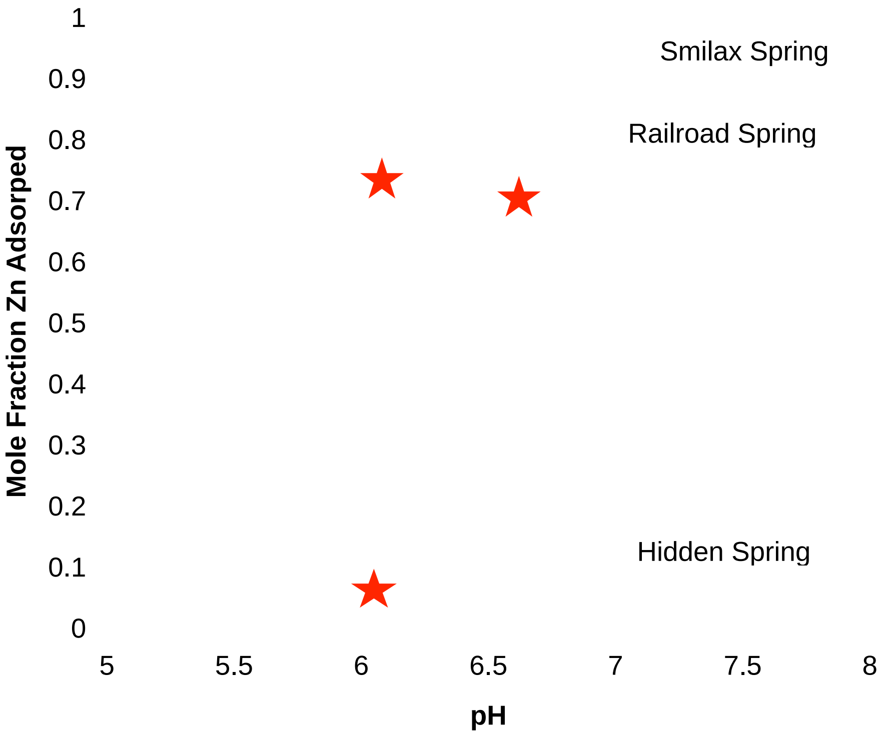


Figure 21: Mole fraction of zinc adsorped to strong sites on hydrous iron oxides for high flow samples from Smilax and Hidden Spring from a July storm event, and Railroad Spring from an August storm event.

Conclusions

The results from the alkalinity titrations and modeling pose implications to the future metal attenuating ability at this site. According to the model (Figure 21), a decrease in pH by as small as 0.5 could result in a 50% decrease in the mole fraction of zinc that remains adsorped to soil particles. Additionally, samples from both springs were found to contain no alkalinity, lowering the ability of these systems to buffer a change in pH. A decrease in pH of soils and groundwater is highly likely within Lehigh Gap Nature Center not only due to the increasing acidity of rain as it equilibrates with the rising concentration of CO_2 in the atmosphere (Bogan et al. 2007), but also as vegetation has just begun to develop across the site and will possibly lower pH through the secretion of organic acids and an imbalanced uptake of positive and negative ions (Viereck, 1996; Ehrenfeld et. al, 2005).

Chapter 7: Conclusions

The area surrounding Palmerton, PA was historically contaminated with metal deposition from a N.J. Zinc Company Smelter. Four areas affected by the metals, the West Plant industrial site, regional waterways, regional soils, and local soils and streams, were studied to determine present day concentrations following the thirty year period of attenuation since the close of the smelter.

Samples from regional waterways indicate the West Plant industrial site is a source of metals to Aquashicola Creek. Samples from the Lehigh River are within US EPA Surface Water Quality Standards.

Zinc, cadmium, chromium, and lead concentrations in soils at the West Plant exceed PADEP standards for non-residential sites in multiple locations. Metals, VOCs, and PCBs are also measurable in groundwater at the site.

Soil samples within a 30 km radius of the West Plant were taken to determine how far metals from emissions extended. Arsenic and lead concentrations do not decrease with distance from the West Plant, indicating other sources may have contributed to their deposition. Cadmium concentrations exceed non-residential standards within 10 km of the West Plant. Zinc concentrations are within residential standards. However, zinc and cadmium concentrations decrease with distance from the plant with higher concentrations found to the east, consistent with the prevailing easterly wind direction.

Metal concentrations in soil from the Lehigh Gap Nature exceed non-residential standards. While there is an increase in zinc and cadmium in the water at LGNC following storm events, the concentrations of these metals are within US EPA Drinking Water Standards. Metal concentrations in each of these four areas are expected to further attenuate over time

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APPENDIX K-2

Background and History

Metals near Palmerton, Pennsylvania were studied in four areas surrounding a former zinc smelter. This pamphlet presents results that show the extent of the metals distribution in the environment.

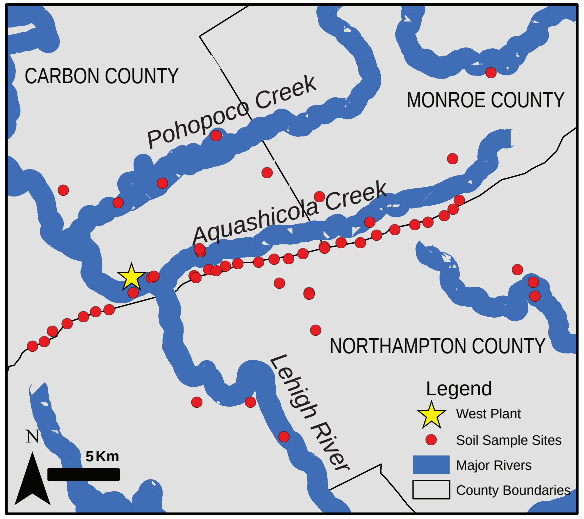
The environment near Palmerton was historically affected by emissions from the New Jersey Zinc Company Smelter that operated from 1898 to 1980.

At the peak of emissions, an estimated 47 tons of cadmium, 95 tons of lead, and 3,575 tons of zinc were emitted each year.

Thousands of acres were deforested on nearby Kittatinny Ridge and Blue Mountain, and high concentrations of metals in soils prevented vegetation regeneration. Aquashicola Creek and the Lehigh River were impaired by high concentrations of metals in groundwater and surface water.

The West Plant industrial site and the accompanying slag pile contained metal concentrations 20 times greater than regulation standards. The site was placed on the US EPA National Priorities List in 1983, and restoration efforts are underway.

The four areas of study include the West Plant industrial site, regional waterways, regional soils, and local soils and streams.



Regional soil sampling sites near Palmerton, PA.

Local soils and waterways were sampled at the Lehigh Gap Nature Center (LGNC, delineated in green). The West Plant industrial site, located across the river, is delineated in yellow. A majority of this land parcel had been contaminated by deposition of metals from emissions from the West Plant.

Cover photos: The first hundred years of the New Jersey Zinc Company, a history of the founding and development of a company and an industry, 1848-1948. (upper photo). LEO Staff (lower photo).

This project was completed by faculty, staff, and students at Lehigh University with assistance from partner organizations. Portions of this project were supported by the US EPA Brownfields Program.

LEHIGH

LEO
Lehigh Earth Observatory

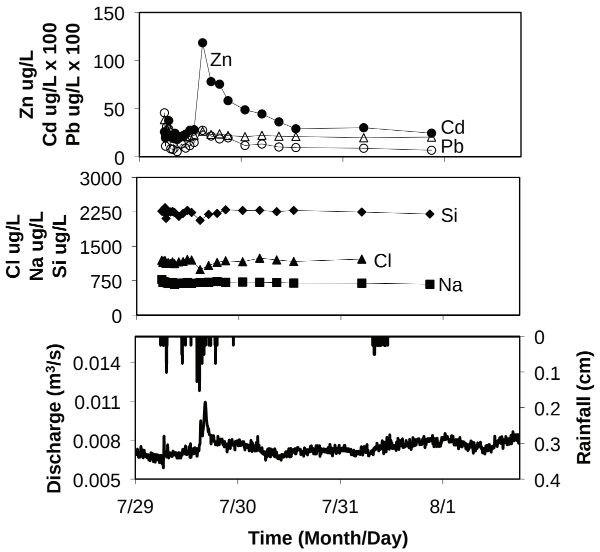
Lehigh Gap
Nature Center

Assessment of Metals in the Environment Near Palmerton, PA

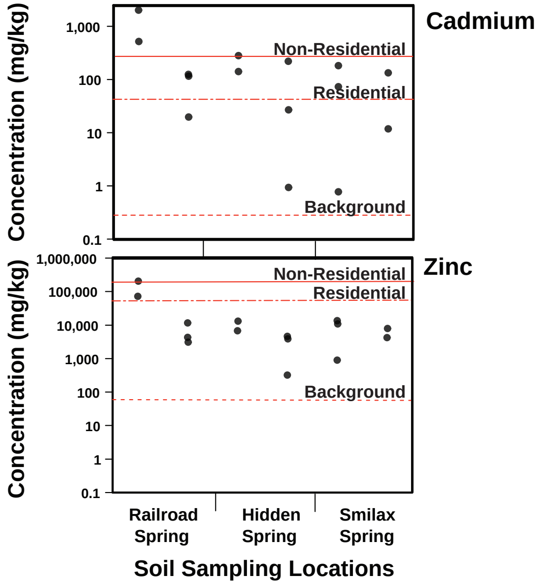
Local Soils and Streams

Soils at Lehigh Gap Nature Center (LGNC) were left intact so that natural recovery could proceed. How much metal remains in the soil and water?

During rain events at LGNC, concentrations of tracer ions such as sodium, chloride, and silicon, as well as lead remain constant, indicating that they are leaking out of the soil from natural processes (figure at right). In contrast, concentrations of zinc and cadmium increase as discharge increases, indicating they are being actively washed out of the soil. The concentrations of these metals are within US EPA drinking water standards.



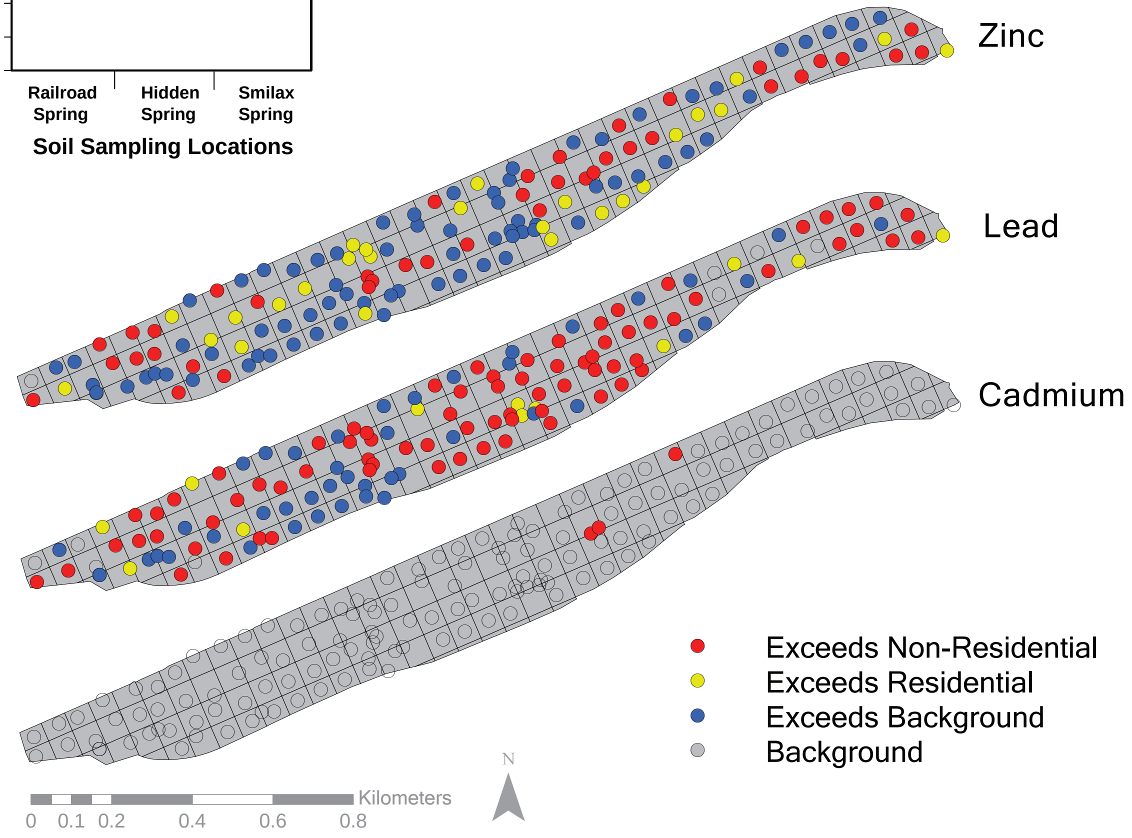
The figure below shows the concentrations of metals in soil samples taken near each spring at LGNC. Some samples at each site exceed residential and non-residential standards for some metals.



West Plant Industrial Site

The West Plant industrial site was a source of metals emissions during smelter operation. Building foundations and a slag pile of the smelting residue remain at the site today. Soil and water samples from the West Plant industrial site were analyzed to determine concentrations of metals in the soil and the ground water.

Results from the soil analyses are presented in map form below, with color symbols indicating concentrations above residential and non-residential regulatory limits. Throughout most of the West Plant industrial site, lead and zinc concentrations exceed regulatory standards.

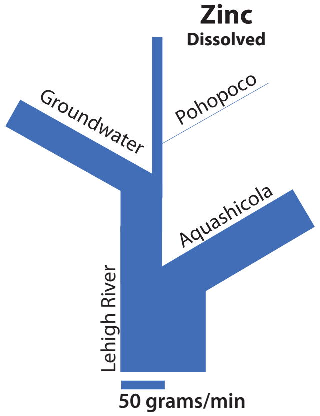


Zinc, lead, and cadmium concentrations in soil at the West Plant industrial site with reference to PADEP soil standards for background, residential, and non-residential standards.

Regional Waterways

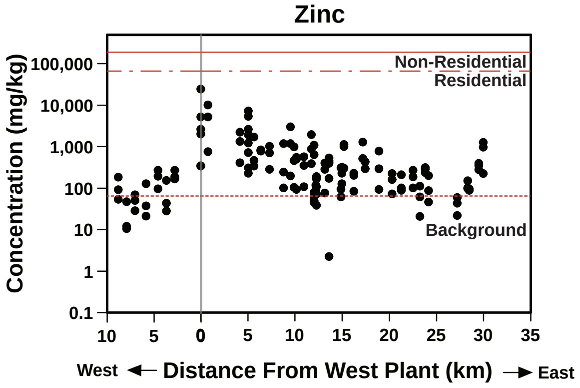
The Lehigh River meets Pohopoco Creek and then flows past the West Plant industrial site. Aquashicola Creek joins the Lehigh River downstream of the industrial site. Water samples from these tributaries and the Lehigh River were collected and analyzed for metals. Zinc concentrations increase due to inputs from groundwater and Aquashicola Creek.

In the diagram to the right, the movement of zinc dissolved in surface water is represented by a "tree" diagram. In this diagram, the thickness of the line shows how much zinc travels in each pathway. Overall water flow direction is top to bottom.



Regional Soils

How far do metals from West Plant industrial site emissions extend? Soil samples within a 30 km radius of the West Plant were taken to determine the distance at which soil contamination is present. Sampling was focused along an east-west transect in the direction of the prevailing wind as it was the area more likely to contain metals from smelting emissions.



Zinc concentration in soil samples as a function of distance from the West Plant industrial site.

Assessment of Zinc, Arsenic, Cadmium, and Lead in the Environment Surrounding Palmerton, PA

Background and History

Metals near Palmerton, Pennsylvania were studied in four areas surrounding a former zinc smelter. This poster presents results from these areas to determine the extent of the metals distribution in the environment.

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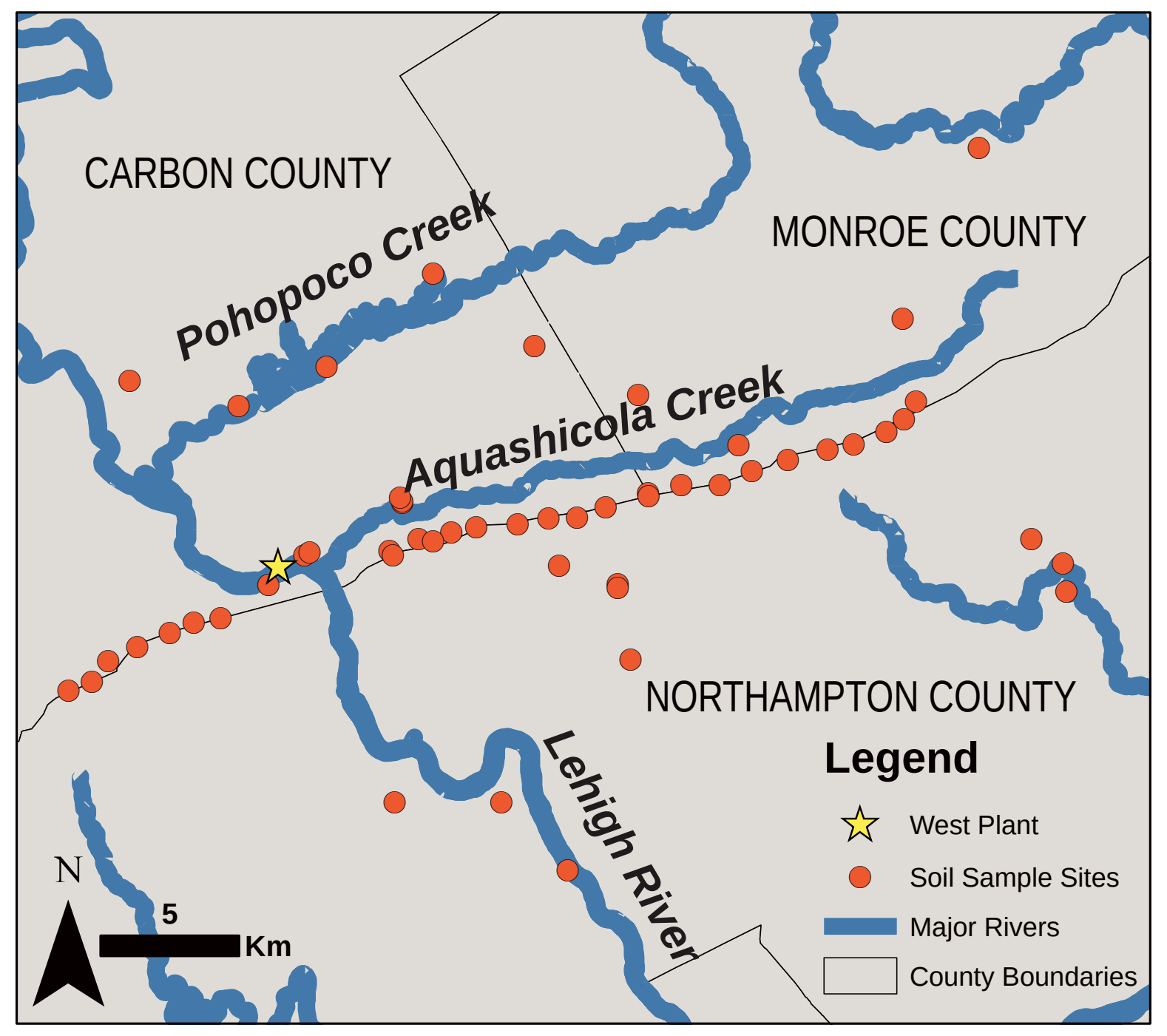
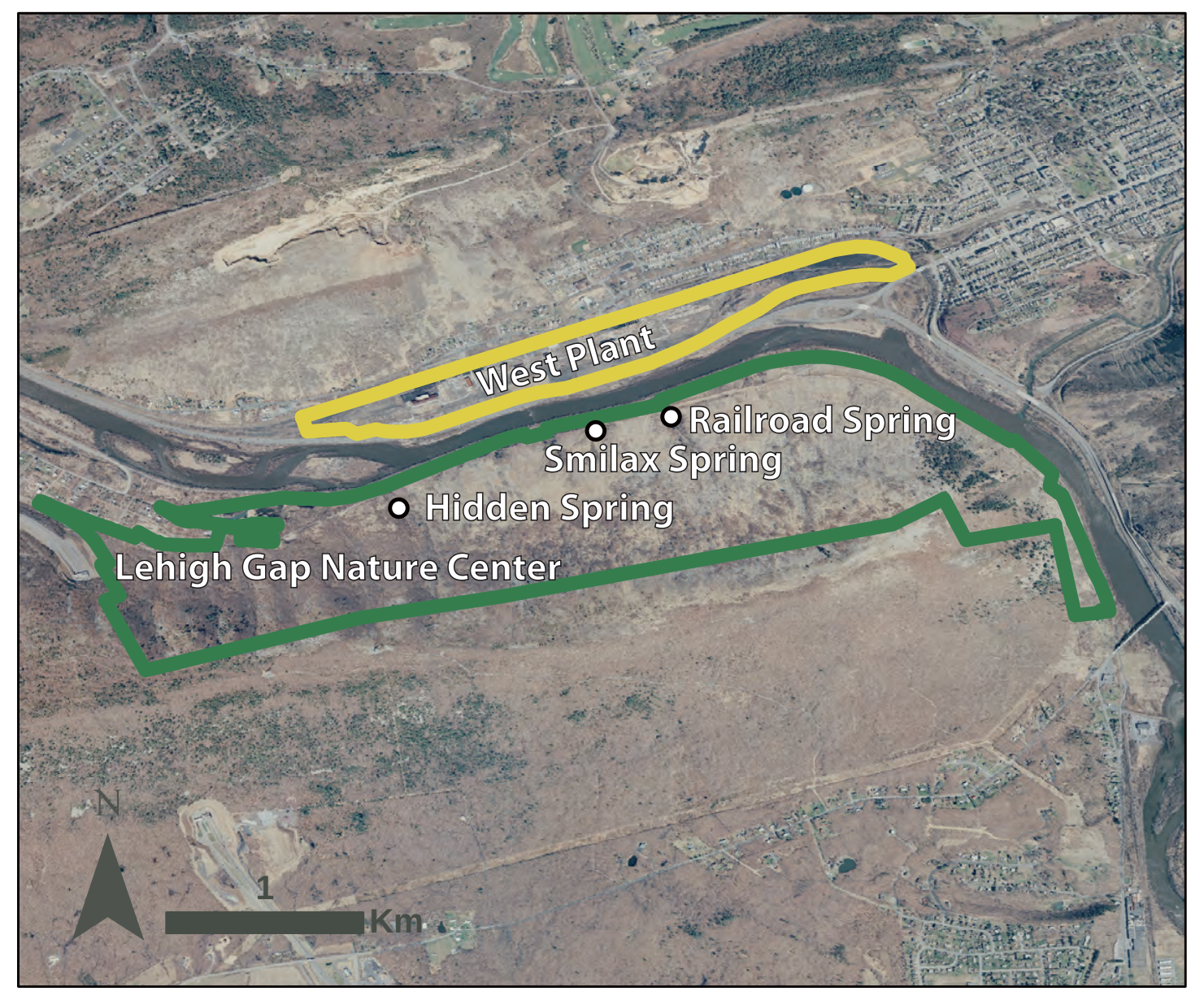
The West Plant industrial site and slag pile contained metal concentrations 20 times greater than regulation standards. The site was placed on the US EPA National Priorities List in 1983, and restoration efforts are underway.



Regional soil sampling sites near Palmerton, PA.



Local soils and waterways were sampled at the Lehigh Gap Nature Center (LGNC, delineated in green). The West Plant industrial site, located across the river, is delineated in yellow. A majority of this land parcel had been contaminated by deposition of metals from emissions from the West Plant.

The four areas of study include the West Plant industrial site, regional waterways, regional soils, and local soils and streams.

The West Plant industrial site is located adjacent to the Lehigh River (see map, left). The West Plant site was the only area studied that contained metals at high enough concentration to require specific attention during the redevelopment process. The rivers and creeks include the Lehigh River and the two main tributaries surrounding the West Plant feeding into the nearby Lehigh River: Aquashicola Creek and Pohopoco Creek.

The regional soils study area was used to determine the distance and persistence of metals away from the West Plant. Local soils and streams were studied at the Lehigh Gap Nature Center, located on the hillslope across the Lehigh River from the West Plant industrial site.

Partner organizations in this project include:

LEHIGH

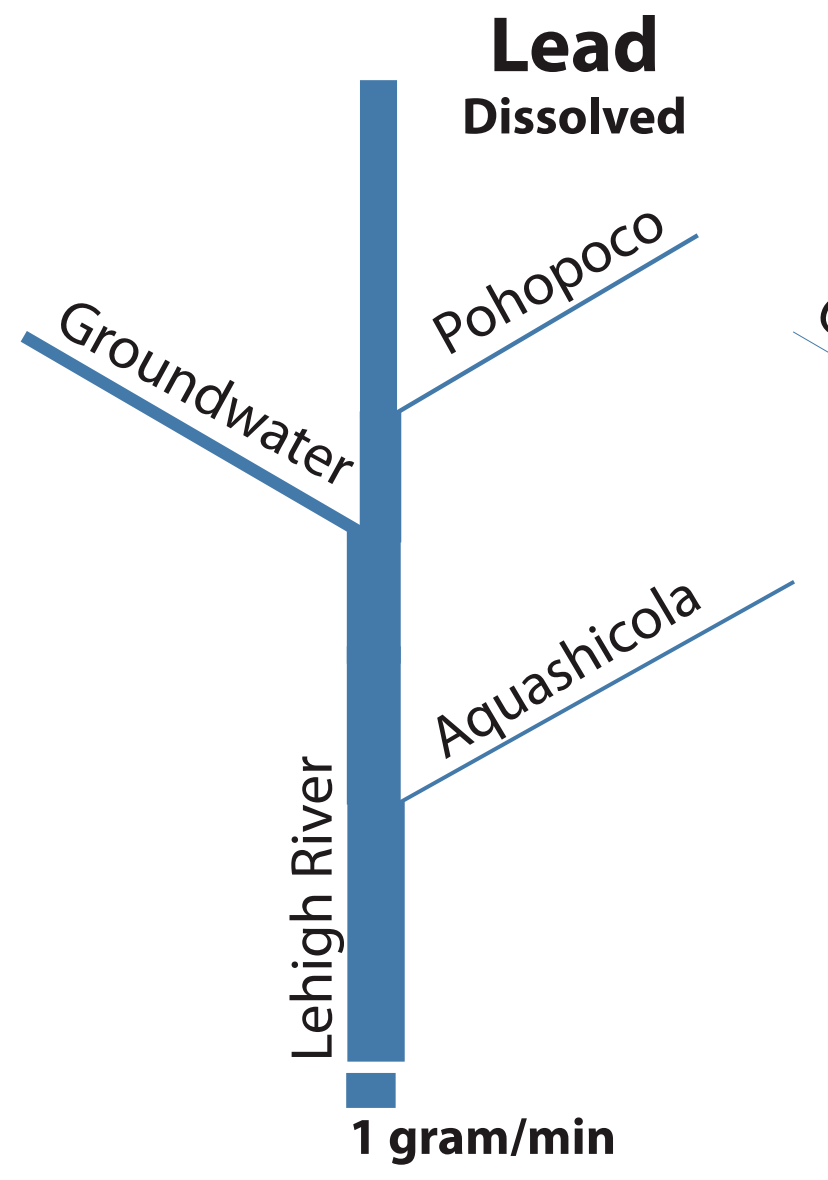
LEO
Lehigh Earth Observatory

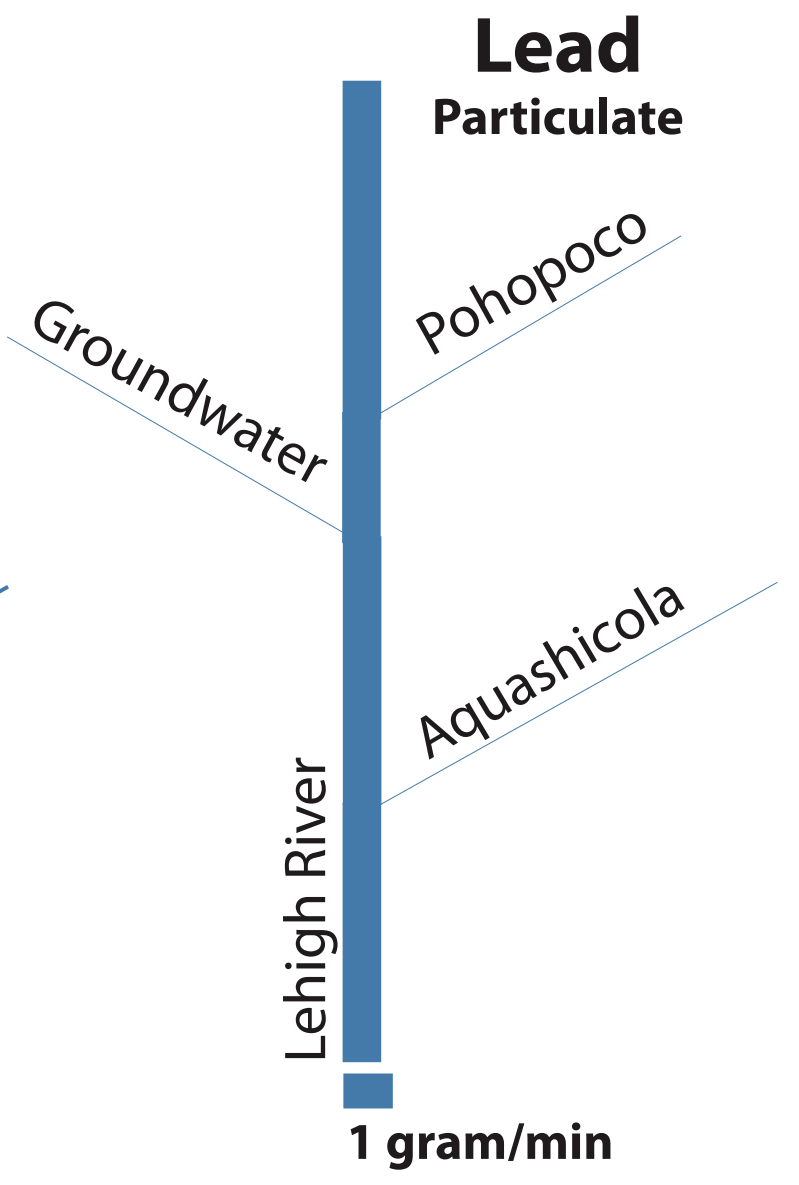
LEHIGH GAP NATURE CENTER

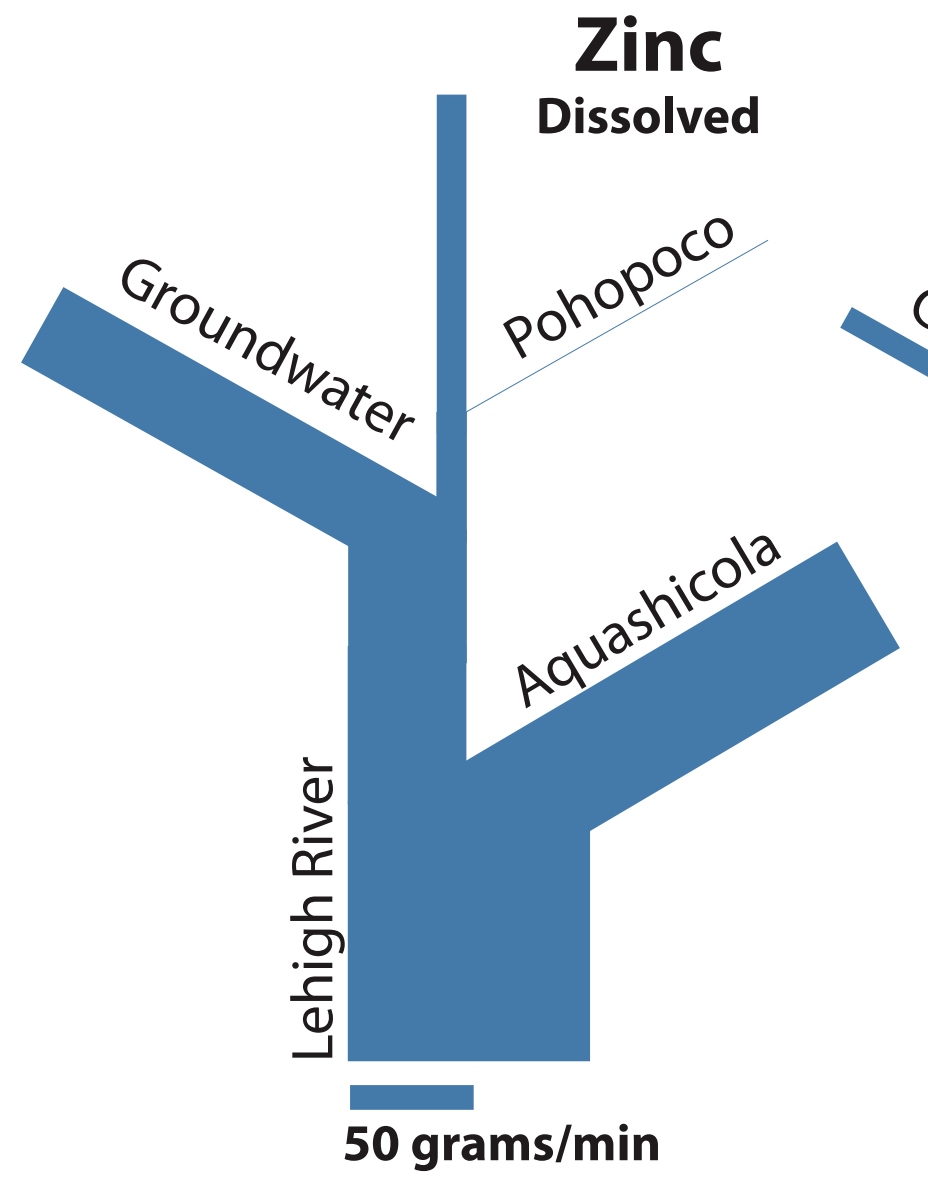
Regional Waterways

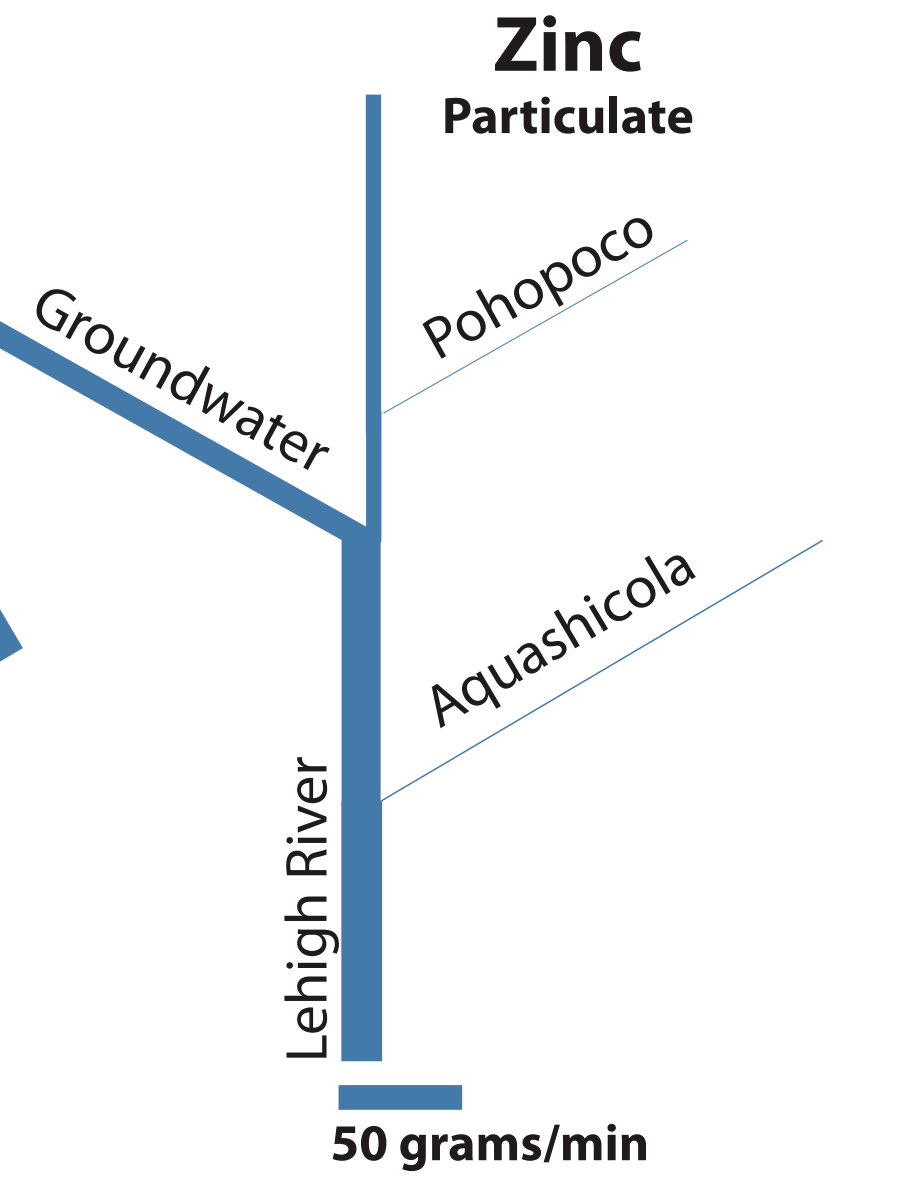
The Lehigh River meets Pohopoco Creek and then flows past the West Plant industrial site. Aquashicola Creek joins the Lehigh River downstream of the industrial site. The Lehigh River is the main river that flows past the West Plant industrial site. Pohopoco Creek and Aquashicola Creek are located upstream and downstream of the smelter site, respectively. Water samples from these tributaries and the Lehigh River were collected and analyzed for metals. While the concentration of lead did not increase near the industrial site, zinc concentrations increased due to inputs from groundwater and Aquashicola Creek.

The figures to the right and below illustrate the relative inputs of each of the tributaries and groundwater to the main branch of the Lehigh River. The width of the lines represents the quantity of metal transported along each stream into the Lehigh River, shown as the central vertical line in each drawing. Metals were analyzed in both the dissolved and particulate forms. Particulate forms include suspended sediments while dissolved concentrations reflect those without suspended sediments.









Only lead exceeded US EPA Drinking Water Standards on one sampling date. However, lead concentrations were within standards for surface water quality. All other metals were within drinking water standards.

Inputs from both Aquashicola Creek and groundwater contribute a significant amount of zinc to the river in both particulate and dissolved forms. This indicates zinc concentration in the river is influenced by water from the West Plant industrial site and the lands surrounding Aquashicola Creek.

West Plant Industrial Site

The West Plant industrial site, a former factory complex, was a source of metals emissions during smelter operation. Building foundations and a slag pile of the smelting residue remain at the site. Soil and water samples from the West Plant industrial site were analyzed to determine concentrations of metals, VOCs (volatile organic compounds), and PCBs (polychlorinated biphenyls) in the soil and the ground water.

Results from the soil analyses are presented in map form to the right, with color symbols indicating concentrations above residential and non-residential regulatory standards. Throughout most of the West Plant industrial site, lead and zinc concentrations exceed regulatory standards for non-residential sites.

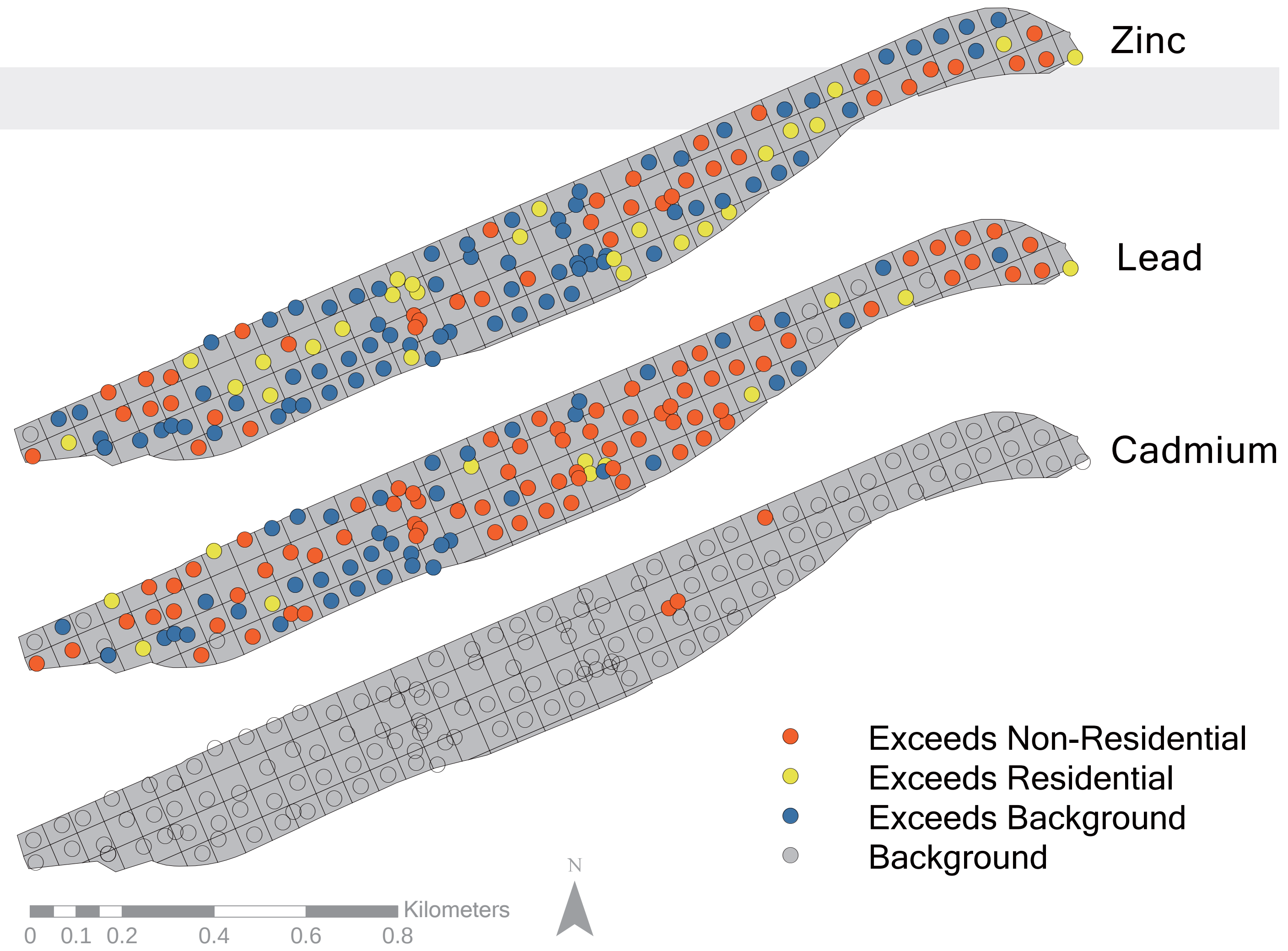
Soil samples exceed non-residential standards for zinc, cadmium, and lead in multiple locations across the site. Arsenic is not measurable in soil samples. The distribution of soil samples containing zinc, cadmium, and lead that exceed regulatory standards show no apparent pattern across the site.

Metals are also present in groundwater in multiple locations, VOCs are present at one site, PCBs are present at two sites. Groundwater appears to be a significant source of zinc to the Lehigh River, as shown in the regional waterways section.

Definition of Scientific Terms:

VOCs: Volatile organic compounds. Compounds of organic carbon with significant vapor pressures. Broad classes of VOCs include paints, thinners, cleaners, chlorofluorocarbons (CFCs), and gasoline additives. Many of these compounds can negatively affect the environment and impact human health.

PCBs: Polychlorinated biphenyls. PCBs are man-made chemicals with high thermal and chemical resistance. Chemically, PCBs are a class of organic compounds comprised of a pair of variably chlorinated benzene rings. PCBs are very stable, have high thermal and chemical resistance and thus resistant to biodegradation. While desirable for industry, these characteristics make PCBs hazardous to the environment.



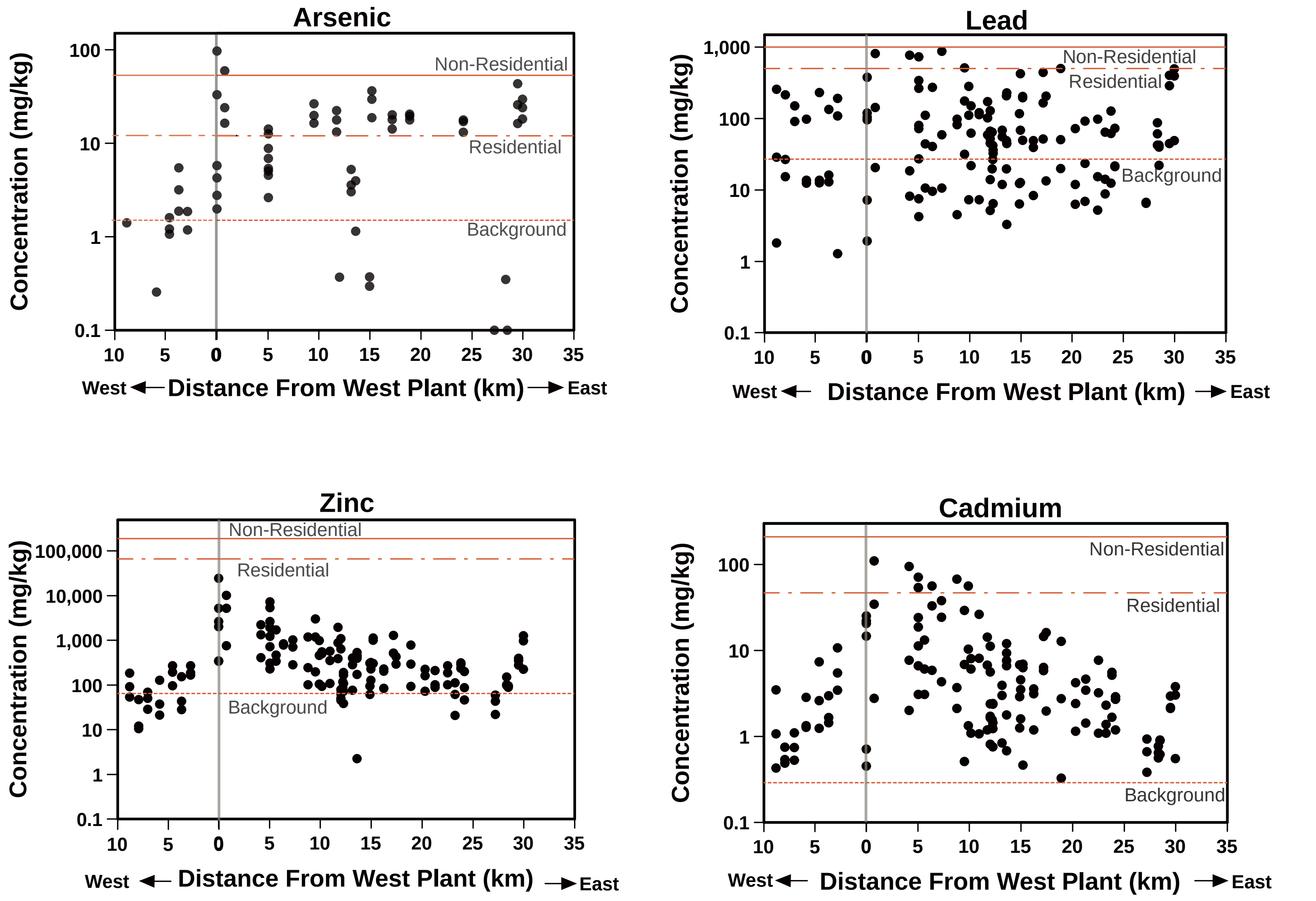
Zinc, lead, and cadmium concentrations in soil at the West Plant industrial site with reference to Pennsylvania Department of Environmental Protection (PADEP) soil standards for background levels, and residential and non-residential property development standards.

Regional Soils

How far do metals from West Plant emissions extend? Soil samples within a 30 km radius of the West Plant industrial site were taken to determine the distance at which soil contamination is present. Sampling was focused along an east-west transect in the direction of the prevailing wind as it was the area more likely to contain metals from smelting emissions.

Arsenic concentrations exceed non-residential standards near the West Plant Industrial Site. Arsenic and lead concentrations in soil do not decrease with distance from the West Plant industrial site. This suggests that other sources may have contributed to the levels of arsenic and lead within the sampling area.

The concentrations of zinc and cadmium in soil samples decrease with distance from the West Plant industrial site and do not exceed Pennsylvania Department of Environmental Protection (PADEP) non-residential standards. Zinc concentrations are within residential standards for all samples. Cadmium concentrations are within residential standards for all samples west of the plant, and in samples taken further than approximately 10 km east from the plant. The higher concentrations of these metals found to the east of the plant are consistent with the prevailing easterly wind direction: metals in emissions were carried further to the east than the west as seen in the graphs below.



Metal concentrations in soil samples as a function of distance upwind (West) and downwind (East) of the West Plant industrial site. Note that for arsenic and lead, very little relationship is observed with distance from the industrial site. Cadmium and zinc are highest near the industrial site, and decrease with distance, suggesting that these data represent background values or non-point sources of these metals.

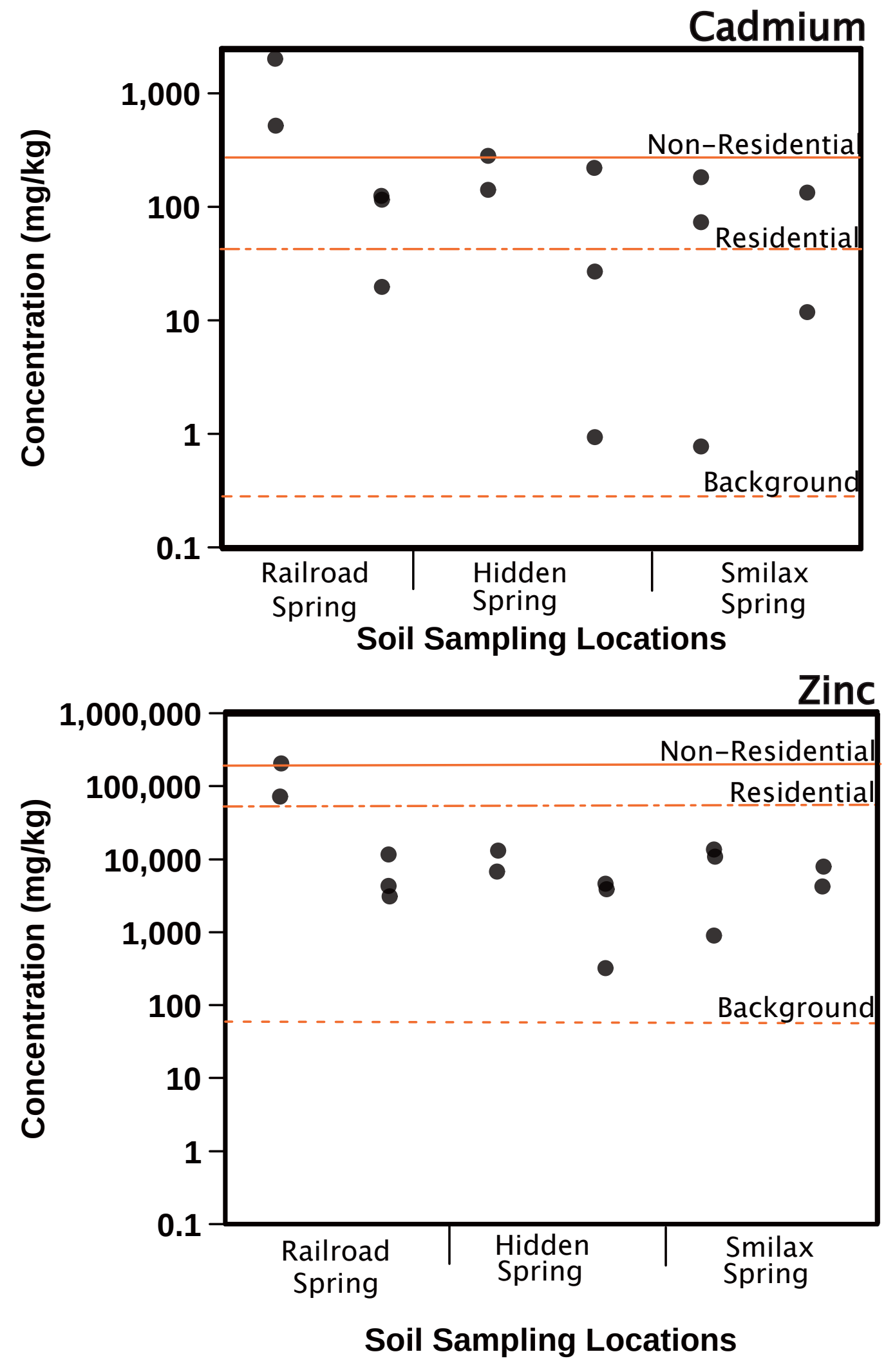
Local Soils and Streams

The Lehigh Gap Nature Center (LGNC) was established in 2002 on 750 acres of the Kittatinny Ridge to the southwest of the Lehigh River, across the Lehigh River from the West Plant industrial site. A majority of this land was defoliated by deposition of West Plant emissions, leaving a barren landscape.

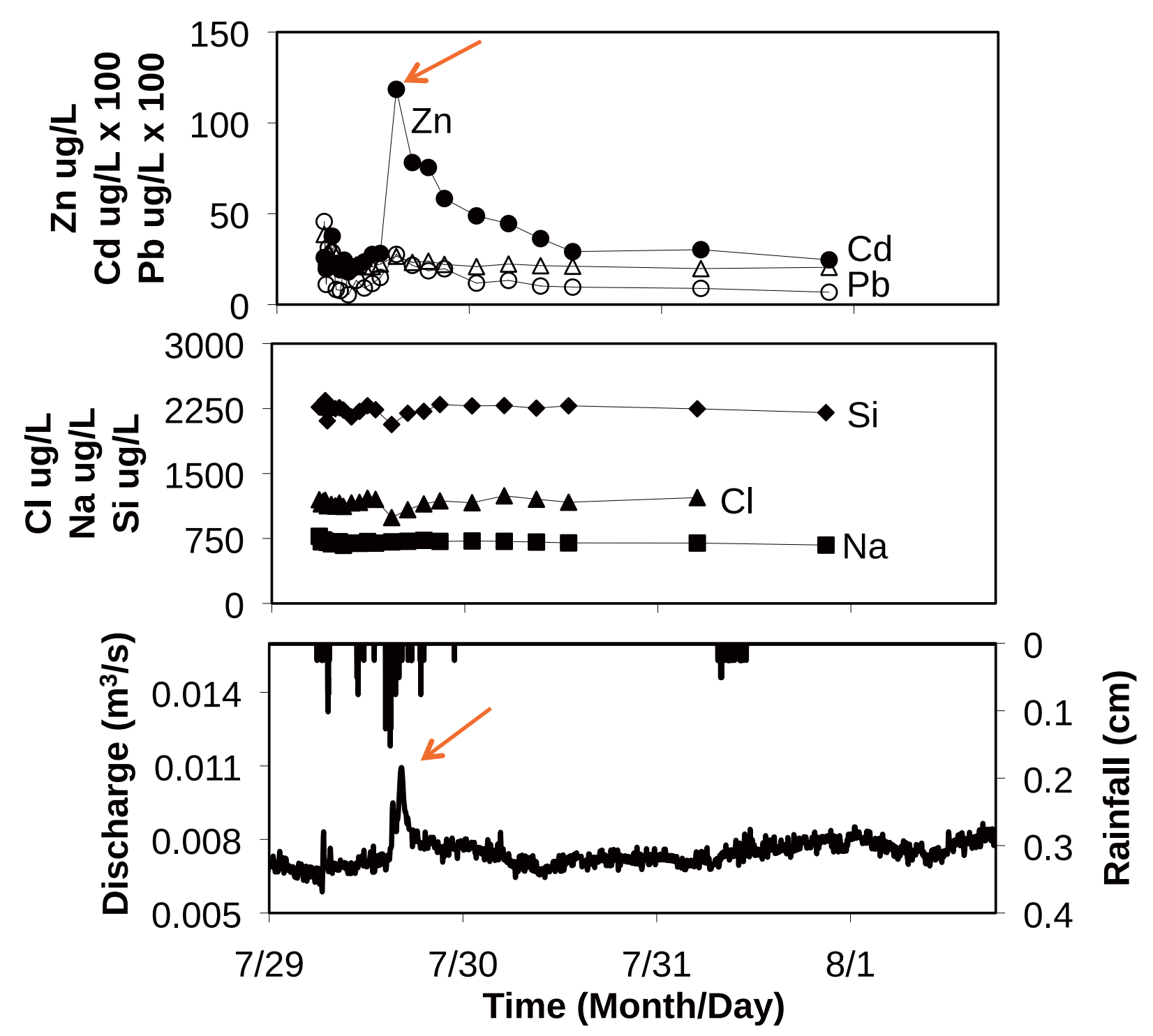
Soils at LGNC were left to naturally attenuate: nothing was done to remove contaminants and instead, warm-season grasses were planted. To assess the effectiveness of this strategy, soil and water samples were collected at three natural springs.

Images of hillslope at Lehigh Gap Nature Center taken in October 2002 and August 2006.

How much metal remains in soils at LGNC? The figures below show the concentrations of metals in soil samples taken near each spring. Data are compared to the PADEP regulation standards. For all metals analyzed, at least one sample was found to have metal concentrations exceeding residential standards. Results of the soil samples are shown in the graphs below, while water analyses are shown in the graphs to the right.



Metal concentrations in soil samples near each spring at LGNC.



How much of the metals in the soil wash out in the water? Is LGNC a source of metals to the Lehigh River? When it rains, the water table rises into areas of soil that were previously unsaturated. When water enters this area, ions that were stuck to the soil grains are released in small amounts.

During rain events at LGNC, concentrations of the tracer ions (sodium, chloride, and silicon) as well as lead remain constant, meaning they are leaking out of the soil continuously from natural processes, while concentrations of zinc and cadmium increase as the discharge of the spring increases, indicating they are being washed out of a contaminant reservoir in the soil as shown by the arrows on the figure above. However, the concentrations of these contaminants found in the water at LGNC are low and within US EPA drinking water standards.

Lehigh University, 2010