2012 Field Station Annual Report

UNIVERSITY of WISCONSIN
UWMILWAUKEE
Field Station

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On the Cover: Field Station staff and volunteers burned Benedict Prairie for the first time in several years. The prescribed fire was necessary to control encroachment by woody species.

About Us

2012 Highlights

- Our new Researcher House used for longer stays by individuals and groups was set up and put into use in 2012.
- Major progress managing woody plant invasion of the Benedict Prairie in Kenosha County.
- Extensive Friends of Cedarburg Bog projects to manage invasive glossy buckthorn in the Cedarburg Bog.
- Management of the Habitat Protection Area at UWM's new Innovation Park campus in Wauwatosa made major progress on control of invasive species.
- Use of Downer Woods on campus for education and research remains strong, and we have made major progress on controlling the invasive plants common buckthorn, honeysuckle, and garlic mustard.
- 41 research projects in 2012.
- Over 10,000 student hours of instruction and group use in 2012.

The UWM Field Station

The UWM Field Station is used as an outdoor laboratory by researchers from various disciplines, including plant and animal ecology, evolutionary biology, ethology, taxonomy, geology, hydrology, and climatology. Located in the Town of Saukville, Wisconsin, about 30 miles (45 minutes) north of Milwaukee, the main Station facility has about 2000 acres including a wide variety of habitats available for research and teaching. The University of Wisconsin-Milwaukee owns approximately 320 acres, most of which were donated by The Nature Conservancy in 1965. Research at the Station has produced 317 scientific publications and 142 theses since 1970.

Natural Areas at the Field Station

The Cedarburg Bog State Natural Area - One of the largest and the most biologically diverse of the wetlands in southern Wisconsin, is accessible to researchers and classes by the Field Station's boardwalk. Shallow and deep lakes, marshes, shrub communities, sedge meadow, hardwood swamp, conifer swamp, and the southernmost string bog in North America are just some of the vegetation types of the Cedarburg Bog. Populations of at least 35 species of higher plants and 19 birds are at or near the southern edge of their range in the Bog. A "Guide to the Natural History of the Cedarburg Bog," which serves as a ready introduction and reference source for researchers and educators using the Bog, is available from the Field Station and on our website.

The Cedarburg Beech Woods State Natural Area – 80 acres of one of the finest mature beech-maple forests in southern Wisconsin. The scale insect associated with beech bark disease has been found in the Cedarburg Beech Woods, although the disease is not known to occur here yet. Adult Emerald Ash Borer beetles were captured in traps at the Station in 2012, although signs of damaged ash trees have not yet been observed. The Cedarburg Beech Woods SNA is likely to experience major changes within the next few years. The beech-maple forest and the Cedarburg Bog are each State Natural Areas, and are classified as National Natural Landmarks by the Department of Interior.

The Sapa Spruce Bog State Natural Area – 12 acres of highly acidic black spruce/tamarack bog and 11 acres of swamp hardwoods. The southernmost black spruce bog in Wisconsin, the small, acidic, Sapa Spruce Bog provides an ecological contrast to the large, neutral-pH, Cedarburg Bog, with which it shares most of its flora.

Old Agricultural Fields – Over 100 acres in various stages of succession are available for experimental research. A history of the use and management of the fields over the past 40 years is maintained. Six separate areas in the old fields have been planted with prairie species native to Wisconsin. A new experimental prairie area planted in the "North Hay Field" in the fall of 2005 is now very well established and serves as the location for Dr. Karron's screenhouse. Preparations to conduct controlled burns of that area were made in 2012.

Management – The primary management that Field Station natural areas receive is maintenance of trails and control of invasive exotic plants. Glossy buckthorn (*Rhamnus frangula*), common buckthorn (*Rhamnus cathartica*), Tartarian honeysuckle (*Lonicera tatarica*), autumn olive (*Elaeagnus umbellata)*, multiflora rose (*Rosa multiflora*), meadow parsnip (*Pastinaca sativa*), purple loosestrife (*Lythrum salicaria*), sweet clover (*Melilotus* spp.), motherwort (*Leonurus cardiaca*), Oriental bittersweet (*Celastrus orbiculatus*) and garlic mustard (*Alliaria petiolata*) are all present, and being controlled in the Field Station natural areas. Purple loosestrife biological control beetles were released in Mud Lake in 2012. Friends of Cedarburg Bog volunteers help Field Station staff with trail maintenance and our efforts to control invasives.

Only glossy buckthorn in the Cedarburg Bog and Oriental bittersweet on private properties south of the Station, are currently so widespread and abundant that their control seems intractable with the hand and mechanical methods we are using elsewhere. Friends of Cedarburg Bog, with grant funding from the Knowles-Nelson Stewardship Fund and the We Energies Foundation through the Natural Resources Foundation of Wisconsin, has been conducting major projects to control glossy buckthorn in parts of the Cedarburg Bog. Planning for buckthorn control work was formalized with the Wisconsin DNR in 2012.

Research and Teaching Facilities

General Facilities

- Office/classroom building with meeting rooms, teaching lab, and computer lab
- A Research Lab constructed in 2004
- Service building – machine & wood shop
- The Farm House for researcher & student housing – The kitchen was redecorated/ painted in 2008
- The Researcher House for longer stays by individuals and groups
- Natural areas marked with a permanent grid – Accurately GPS-located in 2005
- Boardwalk to the center of the Cedarburg Bog – Reconstruction completed in 2009
- 14 aquatic mesocosms (200 gallon tanks)
- Several small boats, canoes, and trailers
- Global Positioning System equipment
- Extensive map and aerial photo collection
- Geographic Information System (GIS) for the Field Station area

Hydrology, Meteorology & Phenology

- Extensive array of environmental sensors recorded by a digital data logger
- Phenological observation garden & native plant observations maintained
- Lysimeter pit in the old-growth forest
- Transect of piezometers from upland to Bog

Animal Ecology & Behavior

- Sound room facility for studies of frog communication and vocalizations
- Large outdoor experimental aviary
- Live traps & animal holding facilities
- Extensive arrays of bird nest boxes
- Insect collection, small mammal & bird study skins

Experimental Garden

- 9 fenced research gardens
- 1 acre Experimental Garden with water & electricity
- A 30' x 60' screen house for studies of pollination biology
- A screen house for studies of plant-insect interactions
- Greenhouse & garden building
- High capacity irrigation well
- Farm & cultivating machinery

Plant Ecology

- Herbarium & Plant lists
- Plant identification lab
- Vegetation sampling & surveying equipment
- Fenced deer exclusion plots in various plant communities and habitats

Outlying Natural Areas

Neda Mine Bat Hibernaculum State Natural Area - An abandoned iron mine, located on the Niagara Escarpment near Mayville and Horicon, Wisconsin, is among the largest bat hibernacula in the Midwest. Up to 150,000 bats of four species (Little brown bats, Big brown bats, Eastern pipistrelles, and Northern long-eared bats) use the hibernaculum. The hibernaculum has the infrastructure and instrumentation to be a productive facility for research on the behavioral ecology of bats at a major hibernaculum. An infrared beam system provides continuous counts of bat flights through the entrances to the mine and we have monitored bat activity continuously since 2000. In 2011 the infrared beam system in one of the four entrances was replaced with a new generation of detectors that will provide more reliable detection with lower maintenance. The mine is also of geological interest; its cliffs provide an excellent exposure of the Niagara Dolomite and the only accessible exposure of the Neda Iron formation.

Neda Beechwoods State Natural Area - Lies on the Niagara Escarpment, just north of Neda Mine and is a well developed stand of American beech (*Fagus grandifolia*) at the western boundary of its range.

Benedict Prairie - Near Kenosha, is a 6-acre tract of virgin prairie along a railroad right of way that has a remarkably diverse flora. A vascular plant species list for Benedict Prairie has been published in the

Field Station Bulletin. Woody plants were cut from the prairie over the winter and the prairie was burned on 20 March 2012 for the first time since 1996.

Downer Woods Natural Area - An 11.1 acre fenced woodlot, is an island of forested natural area in an intensely urbanized setting on the UWM campus. The Field Station assumed management of Downer Woods in 1998. Since that time we have been working very hard to control the garlic mustard, buckthorn, and honeysuckle with funding provided by the University.

UWM Innovation Park – Habitat Protection Area – In the northwestern part of UWM's new Innovation Park campus on the old Milwaukee County grounds in Wauwatosa is an area that has been set aside and dedicated as wildlife habitat. The special target for conservation of this site is as butterfly habitat since it has historically been an important roosting area for Monarch butterflies during their fall migration. The Field Station has been assigned the

initial management and restoration of that habitat area and has been working with the UWM Foundation and a local volunteer

group, Friends of the Monarch Trail, to control invasive plants and begin restoring native vegetation on that site. Marek Landscaping, Inc. was contracted in 2012 for management work on the property, and made excellent progress on invasive control.

Field Station Programs

• 41 active research projects were conducted at the Field Station in 2012.

• Including: 7 M.S. thesis, 3 Ph.D. and 19 studies by researchers from outside of the University.

• 8 papers published during 2012. Several others are in press.

Database Development - The collection of a variety of long-term data is an important part of the Field Station's research program. Examples of our databases include:

• Vascular plant flora of the Field Station area (including approximately 720 taxa) & an excellent herbarium.

• A complete stem map and diameter measurements of all trees in 5.5 acres (2.25 hectares) of the beech-maple woods first censused in 1987.

• Repeated surveys of the entire beech-maple forest at the permanent grid locations.

• A complete, quantitative, survey of the vegetation of the Cedarburg Bog, first conducted in 1991 and repeated in 2006.

• Phenological observations on leaf-out and flowering of standard genotypes of 6 species in a phenological garden, and 26 naturally occurring species at the Station since 2001.

• Long-term weather records from a standard US Weather Service weather station and a Bowen-Ratio energy flux monitoring system.

• Continuous monitoring of bat activity levels at the Neda Mine Bat Hibernaculum since 2000 and of temperatures in the mine since 1997.

• The Charles Weise 30-year study of Dark-eyed Juncos

• The Charles Weise 27-year intensive study of the Black-capped Chickadee,

• The Charles Weise 26-year breeding bird survey of the Cedarburg Bog & upland woods from 1971 to 1996, repeated in 2006, 2007, 2008, and 2011.

• The Charles Weise 30-year bird-netting and banding program conducted in fall.

• The Field Station is a major site for long-term studies of avian vocalizations, including their organization and function.

• GIS developed for the Field Station area.

Educational Programs

• Over 10,000 student hours of instruction and group use in 2012.

• Ten workshops on topics in natural history

• One undergraduate student project.

• Sixteen Friends of Cedarburg Bog programs for the general public on a variety of topics.

• The guidebook to the Bog is available to teachers using the boardwalk for instruction.

• Several field ecology exercises developed for the Field Station are available to instructors

Friends of Cedarburg Bog

The mission of the Friends of Cedarburg Bog is to help preserve and study the Cedarburg Bog and to make the public more aware of its uniqueness. Specifically, their objectives are:

• To support research, including long-term monitoring.

• To assist in land preservation, management and stewardship.

• To develop formal and informal opportunities for public education.

• To generate volunteer labor for natural area management, education, public events, monitoring and research, and facility development and maintenance.

• To raise funds to support the activities of the group as defined above.

In 2012 the Friends sponsored 16 educational events for the general public. Volunteers from the Friends contributed many person-days of labor, including natural area and trail management, publishing a newsletter, raising funds, and sponsoring and providing staff for events. In 2012 the Friends also continued a study to identify the surrounding areas that contribute groundwater supply to the Cedarburg Bog (see abstract by J. Kline). The Friends also continued large grant-funded invasive control projects in 2012 (see notes under Management above). If you are interested in the Field Station's programs and activities, or you wish to support the preservation of the Cedarburg Bog State Natural Area, please consider joining the Friends group. Contact the Field Station for information on how to become involved.

Friends of Cedarburg Bog Information Kiosk at trailhead to Watts Lake

Abstracts of Research

Trypodendron (Curculionidae: Scolytinae) Survey at Sapa Bog, Wisconsin

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My on-going studies of *Trypodendron (*bark beetles) populations in North America have led to the discovery of a previously unrecognized species, *Trypodendron borealis* Swaine, occuring sympatrically with *T. lineatum* (Olivier). Both species infest red spruce in the eastern United States, and white spruce from Nova Scotia, Canada, to Alaska. These two species differ not only morphologically, but also biologically. Each species has a different adult flight phenology and a different moisture condition preference for windthrown spruce in the red spruce forests of New York, Vermont, and West Virginia, and, in white spruce of New Brunswick, Canada. To determine if both *Trypodendron* species occur sympatrically in the white and black spruce forests in Wisconsin, a limited survey was made at Sapa Bog, a black spruce/tamarack bog at the UWM Field Station near Saukville, Ozaukee County, Wisconsin. Two Unitraps, each baited with the pheromone Lineatin and containing the killing agent Vapona, were deployed from May 26 to June 7, 2012, to survey for *Trypodendron* specimens flying at the bog. Surprisingly, no *Trypodendron* specimens were collected. Only a single specimen of the common, non-native ambrosia beetle, *Xylosandrus germanus* (Blandford) (Curculionidae: Scolytinae), was trapped at Sapa Bog. The absence of *Trypodendron* species was unexpected because the pheromone is highly attractive to these species. Reasons for the failure of *Trypodendron* lures to attract any targeted specimens are unknown. One might speculate that there may have been only a limited amount of black spruce host material in a susceptible dying condition available.

Unitraps with Lineatin pheromone lure for *Trypodendron* were placed along the forest edge of mixed hardwood and spruce at Sapa Bog, May 26 to June 7, 2012: one trap on a black spruce (left); one trap within 10 feet of a group of black spruce (right).

Possibly, black spruce may not be as suitable a host as white or red spruce due to its smaller stem diameter. Also, flight dispersals of *Trypodendron* species may have ended earlier than normal because of warmer than normal spring temperatures. Regardless of the reason, the project essentially produced no results for my studies.

Systematics of the Genus *Boechera* (Brassicaceae)

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The genus *Boechera* (Brassicaceae), rockcress, has emerged as a model system for studies of apomixis and ecological genomics. However, to fully exploit the potential of *Boechera* as a model system we must deal with the formidable systematic complexity of the genus. The genus comprises at least 75 sexual diploids and many asexual hybrids (both diploid and polyploid). Recently, great progress has been made toward understanding the complex systematics of *Boechera* by integrating morphological, ecological, and genetic data. Most significant has been the development of a 15-locus microsatellite data set that allows us to determine the genomic make-up, ploidy level, and reproductive mode of nearly any *Boechera* specimen collected within the last 150 years. Although much of our sample set has been obtained from herbarium material, we lacked Wisconsin material from the species *Boechera laevigata (Arabis laevigata*). Herbarium records noted *B. laevigata* as occurring in upland forests surrounding Cedarburg Bog, and a specimen (along with silica-dried leaf tissue) was collected there on 8 August, 2012 (collection # Beck 1277). DNA extracted from this material will be subjected to genotyping at the 15 microsatellite loci. Funded by the National Science Foundation.

Range-edge Genetic Diversity in Black Cherry (*Prunus serotina*)

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Although many hypotheses regarding the limits of adaptation at species' range edges assume lowered levels of genetic variability, this hypothesis is untested in many species. Our groups aim to compare levels of genetic variability in three populations of black cherry (*Prunus serotina*) near its western range edge in Kansas to that found in four populations from its "core" range. The UWM Field Station is one of these core populations (others in MO, GA, and TN), and silica-dried leaf tissue was collected from 20 widely separated trees at the station on 14 August 2012. Allelic variation at three microsatellite loci was assessed in these plants, and this preliminary data set indicated that all 20 individuals were genetically distinctive (20 unique 3-locus genotypes were observed). Future analyses of an expanded dataset will compare levels of diversity between core and edge populations. Funded by the Department of Biological and Environmental Sciences, University of Tennessee Chattanooga.

Genetic Structure of an Invasive Plant in its Native and Introduced Ranges

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Invasive, exotic plants threaten natural ecosystems and can be problematic agricultural weeds. Genetic changes in exotic plants are driven by processes such as founder effects, genetic drift, mixing of plants from widely-separated populations, and hybridization, but more research is needed to develop a general theory of how these forces may stimulate invasiveness. We are investigating genetic variation in the tall goldenrod (*Solidago gigantea*), a species native to North America and one of the most problematic invasive species in Europe. We have extracted DNA from 293 specimens of *S. gigantea* (from both Europe and North America), and from closely related species in *Solidago* subsection *Triplinervae*. We evaluated a small set of microsatellite loci developed for the seaside goldenrod (*Solidago sempervirens*), and found that four loci were consistently amplifiable and interpretable in *S. gigantea*. We are currently developing additional microsatellites for *S. gigantea*, which should enable us to evaluate the genetics of *S. gigantea* in its introduced and native ranges using our existing collection of plant material. Funded by the Research Growth Initiative, University of Wisconsin-Milwaukee.

Identification of Contributing Areas for Groundwater Supply to Cedarburg Bog to Protect Critical Habitat: Hine's Emerald Dragonfly Habitat Assessment and Survey

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Cedarburg Bog is one of only two places where the nymphal stages of the Hine's emerald dragonfly (HED), *Somatochlora hineana,* have been observed in a suspended bog mat. There is a unique combination of factors that make HED habitat viable. While HED are confirmed to live in bog mats, habitat quality is likely marginal, or less productive, than streamlet habitat where HED nymphs can have greater densities. Groundwater flow under the bog mat and the presence of crayfish burrows are keys to HED survival in this particular situation. Areas with high burrow density may be more productive, as burrows and therefore the food resources within them, may be more accessible. A habitat assessment was conducted to document the density of crayfish burrows, size of flarks (hollows oriented perpendicular to the flow of groundwater), and dominant vegetation within the string bog. Crayfish burrow density was found to be similar to that found in Kellner Fen, a confirmed HED breeding site within a bog mat in Door County, Wisconsin. Burrow density was greater in areas dominated by sedges compared to those dominated by giant reed grass, *Phragmites australis*, or mixed vegetation consisting of both sedges and giant reed grass. Crayfish burrows were sampled (limited due to drought) for HED nymphs; however, none were observed in 2012. The hydrogeology portion of this project found that groundwater influence was most abundant in the northern and western portions of Cedarburg Bog. This corresponds to areas of adult activity and potential habitat identified in the past. Future surveys should focus on the northern and western portions of the bog where habitat potential is greatest. Funded by the Wisconsin Coastal Management Program through a grant to the Friends of Cedarburg Bog with additional support from Wisconsin Geological and Natural History Survey, Wisconsin Department of Natural Resources, and University of Wisconsin-Milwaukee.

Wildlife Monitoring in Ozaukee and Washington Counties, Wisconsin

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The Ozaukee Washington Land Trust (OWLT) began wildlife monitoring in 2004, as a means of assessing the success of habitat restorations, and identifying important wildlife resources for OWLT habitat management and acquisition and protection planning. In 2012 we continued herp and bird monitoring.

Wisconsin Herp Atlas

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The Wisconsin Herp Atlas is a distribution database of amphibians and reptiles in Wisconsin. The Atlas was initiated in 1986 at the Milwaukee Public Museum, with the cooperative support of the Natural Heritage Inventory Program (WDNR) and The Nature Conservancy. The Atlas collects and verifies records obtained from museum collections, field surveys, the literature, and field notes provided by volunteer observers throughout the state. Over 450 new county records have been confirmed by the project. The data collected helps to map species distributions, document rare species occurrences, analyze distribution trends, examine habitat requirements, and plan conservation priorities. In 2006 the Atlas was abandoned by the financially troubled Milwaukee Public Museum, and in 2007 it was re-established through the UWM Field Station, where it now resides, and currently houses 70,003 occurrence records for Wisconsin.

Wildlife Ecopassage Monitoring

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Wildlife ecopassages are designed to afford safe passage for wildlife across roadways, thereby reducing road mortality and improving traffic safety. Ecopassages allow wildlife to pass underneath the highway lanes, and maintain habitat and population connectivity on the landscape. This can be especially important in maintaining genetic interchange across highways for more sedentary wildlife such as amphibians and reptiles. Little data are available for evaluating the conservation effectiveness of these structures. This project installed wildlife cameras and is conducting surveys of 6 ecopassages in Waukesha and Racine counties, Wisconsin, to collect data on patterns of wildlife use. Species documented to date include: raccoon, opossum, eastern cottontail, house cat, mink, woodchuck, gray squirrel, weasel (probably long-tailed), white-footed or deer mice, white-tailed deer, American robin, house sparrow, song sparrow, dark-eyed junco, barn swallow, eastern milksnake, snakes, painted turtle and American toad. We continued data collection in 2012. Funded by C.D. Besadny Conservation Grant, Natural Resources Foundation of Wisconsin, and Wisconsin Department of Transportation

Reproduction in Cedar Lake Blanding's Turtles

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This radio telemetry study is monitoring female Blanding's turtles to determine nesting sites and collect data on reproductive success in Washington County, Wisconsin. Study objectives are to build upon past data defining critical habitat needs for this population, and specifically identify nesting areas and collect data on nesting success. Prior studies in this area have documented activity ranges, unsuccessful nesting, and important foraging and over-wintering sites. In 2012 two adult females were tracked throughout the season and into hibernation. No nests were found. Funded by Cedar Lakes Property Owners Association and Cedar Lakes Conservation Foundation.

Amphibian Monitoring for the National Park Service Great Lakes Network

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The goal of this project is to finalize amphibian monitoring protocols for the Western Great Lakes Park Network. A protocol using automated recording systems and supplemental visual surveys was completed in 2012, and a new award let for assisting with implementing the program in 6 parks in 2013. Funded by the National Park Service.

Enhancing Ecological Productivity of Milwaukee Estuary Area of Concern Watersheds

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The goal of this project is to assess and map wildlife habitat in the Milwaukee River Basin for ranking habitat restoration sites for best value. Work continued in 2012. Funded by an EPA Great Lakes Restoration Initiative award to Ozaukee County.

Effects of Climate Change on Wandering Spider Assemblages in Cedarburg Bog

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Spiders have been found to be greatly influenced by climate, which makes them a good study organism for climate change. Our objective was to look at climate change related changes in spider assemblages in Cedarburg Bog because of its unique attributes. Cedarburg Bog, Ozaukee County, Wisconsin, is a protected natural area that is a part of the UW-Milwaukee Field Station; it is the southernmost string bog in the nation and has been protected since 1952. Many plants and animals reach their southern and northern most ranges at Cedarburg Bog so we expect to see a response due to climate change much more quickly than in other areas. Spiders were collected from May 2000 to May 2001 and May 2011 to May 2012 from five habitats on the site. The sampling included the use of beat sheets, sweep nets, and brush samples along with pitfall traps reset each month and litter samples collected and run through Berlese funnels. Adult spiders were identified to species level and the data sets were then compared for differences in habitat preference, phenology, abundance and presence or absence. We also examined the climatological record to see if changes have occurred during this period which could account for any shifts in the spider communities. There was an overall decrease in temperature and growing degree-days and an increase in precipitation and growing season length. Spider species sampled decreased between the sampling periods from 59 to 47 species. Sixty-one percent of the species collected were southern spiders and 39% were northern. Of the species collected, 13 species appeared at Cedarburg Bog in 2011, 26 species disappeared after 2001 and 35 species persisted throughout the sampling period. The spiders that appeared had an average northernness index of 30.7%, the species that disappeared had an average northernness index of 45.9% and the species that persisted had an average northernness index of 40.8%. Species tended to move to drier habitats over the decade between samplings. The phenology of the spiders did not follow a consistent pattern but most species moved to earlier or later development. M.S. Thesis research, Dr. Michael Draney, Advisor.

Analysis of Phosphoglucose Isomerase (PGI) Within and Among *Habrotrocha rosa* metapopulations

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Phosphoglucose isomerase (PGI), a dimeric enzyme that catalyzes the reversible isomerization of glucose-6-phosphate and fructose-6-phosphate, plays a key role in glucose metabolism and the resupply of ATP. PGI variants have been correlated with habitat migration in metapopulations of the endangered Glansville Fritillary butterfly, and in metapopulations of the terrestrial rotifer *Macrotrachela quadricornifera*. The bdelloid rotifer *Habrotrocha rosa* exists as a metapopulation in the leaves of the northern pitcher plant *Sarracenia purpurea*. We hypothesize that variation in *H. rosa* PGI isozymes may correlate with its life history - these rotifers must migrate to a new leaf habitat patch before the old leaf dies. Our sampling scheme was designed to provide samples from within habitats, between habitats and among locations on a bog. We also tested for reproducibility of isozyme patterns by collecting rotifers from four other bogs. Three rotifers were randomly selected from each pitcher sample, and each one became the foundress of a clone representing one *H. rosa* genotype that was present in the pitcher on the date of collection. Sampling was conducted at all sites within a two week period to avoid any time effects. We examined PGI using the protocols of Gomez (1998) and Hebert (1993) with modifications. Contrary to the data in the literature for other invertebrates, we found that the *H. rosa* clones from Cedarburg Bog exhibited identical heterozygous genotypes for phosphoglucose isomerase. This strong stabilizing selection poses the question of whether this rotifer travels from one habitat patch to another phoretically, and therefore does not rely upon high ATP demand for migration. We are currently analyzing the results from the other sampling sites. We are also investigating how phoresy might take place.

Pitcher of *Sarracenia purpurea*

Food Abundance, Timing of Breeding and Reproductive Success in Tree Swallows

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Tree swallows are a widespread aerial insectivore, whose timing of egg-laying has shifted earlier by nine days since the 1950s. This adjustment in the timing of breeding may be a response to warmer Spring temperatures and an earlier emergence of aerial insects, the primary food source for breeding tree swallows. The Mismatch Hypothesis predicts that reproductive success is maximized when animals synchronize their reproduction with the food supply, such that nestlings are raised during the peak in food abundance. In 2012 we continued a long term study of tree swallows at the UWM Field Station to examine whether tree swallows adjust the timing of egg-laying so that offspring are raised during the peak of food abundance as predicted by the Mismatch Hypothesis. We measured daily temperatures, food supply, as well as egg-laying and chick-rearing dates of breeding swallows. Understanding the mechanisms influencing the timing of reproduction has taken on new urgency as climate change is altering environmental conditions during reproduction, and there is concern that species will not be able to synchronize their reproduction with changing food supplies.

Survey of Insect Species Feeding on *Rhamnus alnifolia* and *Rhamnus lanceolata*

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In summer, 2012, I continued to search for herbivorous insects feeding on alder-leaved buckthorn (*Rhamnus alnifolia*) shrubs growing in Cedarburg Bog. I searched the shrubs on two or three occasions in the summer of 2012. As in 2011, there was little evidence of insect feeding, either on leaves or within fruits. I failed to find a single insect in the act of feeding on this plant. It is well known that few insect species feed on the invasive buckthorn, *Rhamnus cathartica*, but this is to be expected, since *R. cathartica* has been in North America a relatively short time. I continue to be surprised at the lack of damage to *Rhamnus alnifolia*, a native buckthorn.

Immune Genes and Male Ornaments in the Common Yellowthroat

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In 2012 we continued our studies of the common yellowthroat with an experiment to test the relationship between immune genes, parasites, and male ornaments. Male common yellowthroats possess two sexually selected ornaments: a prominent black mask and a bright yellow bib. Previous work has revealed that females in Wisconsin preferentially mate with males with larger masks and that the size of this mask is positively correlated with variation at the major histocompatablity complex (MHC). The MHC is a major component of the vertebrate immune system and genes in this complex encode proteins that recognize foreign pathogens. An integration of these immune genes, male ornaments, and parasites can be found in the Hamilton-Zuk hypothesis. This hypothesis states that females chose males with superior ornaments because these ornaments reveal heritable resistance to parasites that will be passed on to the female's offspring. We attempted to test this hypothesis and provide a more direct link between male ornaments and immune genes, by using an anti-malarial drug to experimentally clear malarial parasites from males and monitor reinfection rate and intensity. We would then be able to examine if there was a correlation between rate or intensity of reinfection, immune gene variation, and the size of the male's mask. Although malarial infections were not successfully cleared experimentally, we did find that many males clear infection naturally over the course of the summer months. This field season has also provided us with data that will be used in future geographical studies of these birds. PhD. research, Dr. Peter Dunn, Major Advisor.

Preference Functions and the Evolution of Multimodal Signals

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Signal production and reception often encompass various modalities of communication. For example, a calling frog cannot but produce a visual component as it inflates and deflates its vocal sac to emit an acoustic signal. A frog calling in a pond also creates water surface waves, and calling on a branch he creates vibrational signals. Thus, a simple "acoustic signal" actually encompasses three modalities (acoustic, visual and surface wave/vibrational). An increasing number of studies show that multi-modal signals are common and that mate choice is often based on multiple signal modalities, yet we know relatively little about the evolution of multimodal signaling. To better understand the evolution of multi-modal signals in frogs, we made detailed descriptions of visual (color, size) and vibrational portions of the signals of Gray treefrog males, and conducted playback experiments with female gray treefrogs to evaulate whether they are attracted to visual (video of calling male) and water wave (shaker-created waves) signal components. Preliminary results indicate that preferences of female gray treefrogs are altered depending on the combination of signal modalities available during mate choice. For example, the presence of a visual signal component in addition to the auditory one increases female acceptance of short duration calls, which are larely rejected if only the auditory component is present. Funded by the Research Growth Initiative, UWM.

Germination of Cultivars of Burning-bush (*Euonymus alatus*) under Field Conditions

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Euonymus alatus is an introduced, commercially important species that has the potential to become invasive. The purpose of this study is to determine the relative establishment ability of some of the most common horticultural varieties that have been developed in different hardiness zones to assess whether some varieties pose less risk of becoming invasive than others. This project was initiated in 2010. Six blocks were set out in the research garden of the UWM Field Station. Each block consisted of 6 plots, 5 of which contained 150 fruit from a single *Euonymus alatus* cultivar and the remaining plot was blank. The 5 cultivars of *Euonymus alatus* being studied are 'Compactus', 'Nordine', 'Select' (Fire Ball™), 'Timber Creek' (Chicago Fire™), and 'Tures'. By the end of the field season 2011 no fruit had germinated. Colleagues in Connecticut reported similar results; their *Euonymus alatus* seeds took two years to germinate. In spring of 2012 we recorded germination. However, by the end of the 2012 growing season no living *Euonymus alatus* plants were recorded. It is likely that the extreme drought conditions of the 2012 growing season impacted the survival of the germinated seedlings. We plan to assess germination and survival a final time in spring of 2013 as the last measurement taken in this trial. The UWM Field Station site is a portion of an experiment to rate cultivars of plants in terms of invasiveness based upon seed production, germination, and survival. Funded by the Cooperative State Research, Education, and Extension Service, and U.S. Department of Agriculture.

Use of Mark-Recapture Techniques to Estimate Milksnake (*Lampropeltis triangulum*) Populations in the Upper Midwest.

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Published data on population characteristics of milksnakes (*Lampropeltis triangulum*) are rare, with most focused on estimates of density per area in populations from the western portions of its range. Information on Wisconsin populations does not exist, despite the importance of such baseline data for future conservation efforts. The UWM Field Station contains a rich herpetofauna that previous surveys have determined includes milksnakes. We attempted to study several population parameters of these snakes through the use of mark-recapture methods. Surveys consisted of four periods, each lasting about 2 hours, over two days in late May/early June. Each survey involved checking cover objects and conducting random visual encounter surveys throughout 6.1 hectares of Field Station property. Surveys were either conducted by JMK and TJM, or in conjunction with a Field Herpetology course conducted at the Field Station in 2006, 2008, 2010, and 2012. To-date, six annual sampling efforts have been completed (2006-2012). Upon capture, snakes were marked with Passive Integrated Transponder (PIT) microchips, a commonly employed technique to mark snakes for future identification. Throughout the duration of this study to-date, annual captures of novel individuals ranged from five to nine annually (annual recaptures ranging from zero to seven individuals). This resulted in population estimates ranging from 5.6 to 12.4 individuals (density estimates of 0.92 to 2.03/ha). Small vertebrate populations are dynamic, and the variation in results obtained over time further support the notion that long-term datasets are critical when analyzing population parameters. Therefore, it will be important to continue this research for a number of years to determine if discernable trends have occurred.

The Utility of Aerial Photography in Detecting Beech Bark Disease Occurrence and Severity in Wisconsin and Michigan

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Beech bark disease (BBD) is an important exotic insect and disease complex that threatens the current health and future of Wisconsin's American beech forests. BBD was first identified in Wisconsin in September 2009 but the extent and severity of the infestation is not yet known. Michigan forests have experienced high mortality of American beech due to BBD and the complex has spread quickly throughout the state since its identification in 2000. Forest Inventory and Analysis (FIA) plot data has identified significant amounts of American beech in Wisconsin's forests, concentrated on the east coast along Lake Michigan and on the Menominee Indian Reservation. BBD has the potential to have a significant impact on Wisconsin's beech forests if early detection and management is not implemented. The establishment of a monitoring and impact analysis system to track this disease's temporal and spatial change is of utmost importance before any substantial damage occurs. Solid baseline data obtained now will allow precise determination of the impacts that this disease has on beech trees and northern hardwood forest ecosystems as a whole. The utility of aerial photography in detecting and tracking BBD progression will be explored through the use of change detection analysis techniques applied to sequential years of aerial imagery data in areas where ground data has been provided by the monitoring impact and analyses system. These two sources of data will be used complementarily to provide a more comprehensive knowledge of the progression and effects of BBD in Wisconsin and Michigan forests. This project is funded by a grant provided by the USDA Forest Service.

Evolution of Marginal Populations of an Invasive Vine Increases the Likelihood of Future Spread

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Biological invasions are homogenizing the Earth's biotic communities. To predict future invasions we must understand how evolution of invasive species interacts with anthropogenic environmental change. This study compares Japanese honeysuckle (*Lonicera japonica*) plants from the core (100-150 years old) and the margin (65 years old or younger) of the invaded range in North America, to determine whether recent evolution increases the probability of future expansion. Plants from multiple populations in the core and margin were compared in two habitats beyond the northern range edge to assess the potential for populations from these sources to invade novel areas and continue range expansion. We compared these data to data from other work in this system, to assess the effects of latitudinal climate on *L. japonica* spread. Beyond the northern range edge, plants from the northern margin reached greater size and had 54% greater final survival than plants from core populations. Across the range, winter mortality was predicted by latitude, temperature and the origin of individuals. In particular, winter mortality increased with increasing latitude and decreasing temperature, and across the range, core plants had 39% higher winter mortality than margin plants. These results show that prior evolution in this invasive species may increase probability of further spread northward of margin populations, especially with the anthropogenic rise in global temperatures. Funded by the Jeffress Foundation. PhD. Dissertation research of F. Kilkenny, Dr. Laura Galloway Major Professor

Web-building Behavior and Vibrational Cues: Do Spiders Eavesdrop on their Prey?

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Flexible foraging behavior is crucial for predators, which need to locate and capture moving prey. Even web-building spiders, which are sit-and-wait predators, use cues from their surroundings to make foraging decisions, which are manifested as web-building behavior. Here I focus on substrate-borne vibrational cues, which are commonly used by insects for communication along plant stems. What isn't fully understood is the extent to which spiders utilize these cues in making foraging decisions. That is, how does the presence of vibrational cues specifically affect spider web-building behavior? In this study, I test the hypothesis that web spiders exploit vibrational cues to assess local prey availability, and modify their web-building behavior accordingly. During the summer of 2012, I conducted preliminary research to look at natural distributions of spiders and insects that communicate with vibrations. Twice during the summer, I sampled 42 meadow plants at the UWM Field Station in a field known to have spiders and Publilia treehoppers, a vibrationally-communicating insect. I used contingency tables and Chi-square tests to check for significant co-occurrences of spiders and potential prey. Results at this time are inconclusive due to a gross scarcity of spiders in the samples that could have been caused in part by an unusually hot and dry summer. M.S. Thesis research, Dr. Rafael Rodriguez, Adviser.

Determinants of Alternative Mating Tactics in *Hyla versicolor*

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Advertisement calls are used by male *Hyla versicolor,* gray treefrog, to attract potential mates. Males unable to effectively compete using attractive calls will resort to alternative mating tactics, otherwise known as satellite behavior. Satellite males will position themselves near an attractive calling male and attempt to intercept females attracted to the caller. During the 2009 – 2012 breeding seasons, I investigated the factors that mediate the expression of alternative mating tactics in *H. versicolor*. Satellite males will sometimes call when the calling male is removed. If both males called, then the caller/satellite male pair vocalizations were recorded to analyze phenotypic traits between males. Otherwise, only the calling male was recorded. Random calling males and the nearest calling neighbor were also recorded. I found that satellite males were smaller than calling males but did not differ in body condition. When comparing call traits, I found that satellite males had significantly reduced calling effort, higher frequency calls, and smaller frequency amplitude differences than callers. There were no differences between calling males with a satellite, random calling males, and calling neighbors. Two choice mating trials were conducted to determine female preferences in frequency and frequency amplitude differences. Females preferentially discriminated against frequencies of satellite calls and satellite frequency amplitude differences, which suggests that males utilize satellite behavior when they are unable to attract females. Data analysis is continuing. M.S. Thesis research, Dr. Gerlinde Höbel, Advisor.

Identification of Contributing Areas for Groundwater Supply to Protect Critical Habitat at Cedarburg Bog

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Cedarburg Bog in Ozaukee County is a 2500-acre wetland complex of many plant communities that support a wide diversity of plants and animals. As at true bogs, rainwater received directly is an important part of the Cedarburg Bog's water supply. However, the Cedarburg Bog also receives groundwater. This groundwater contribution is what drives the uniqueness and diversity of the wetland community types and the species that depend on them. Of particular interest are the Hine's emerald dragonfly (*Somatochlora hineana*) and eastern prairie fringed orchid (*Platanthera leuocophaea*), both of which are state and federally listed rare species. Our study looked at the hydrogeology of the Bog; the contributions from groundwater and the geology that helped form the bog; and, using the results,

expanded on previous habitat assessments for the Hine's emerald dragonfly to guide future monitoring.

Groundwater at the Bog originates as local recharge as rain and snowmelt infiltrate up-gradient of the Bog. We used well construction reports, constructed several wells and collected data from previous studies to delineate the area contributing groundwater to the Bog. The well construction reports, surface geophysics, and maps of the glacial geology for the region were used to reconstruct the geology that formed the Bog and continues to play a role in the groundwater flows to and from the Bog. The data we collected will be used to provide estimates of the water budget for the Bog. We can delineate those parts of Cedarburg Bog that are most dependent on groundwater flows from outside the Bog's borders and be able to understand how land use changes might impact those flows. This information can then inform protection strategies such as education, transportation and land use planning, zoning, conservation easements and land acquisition. The hydrogeologic picture combined with habitat assessment for the Hine's emerald dragonfly led to identifying the best potential habitat areas within the extensive bog mat, which will help to focus future monitoring of this rare species. Funded by the Wisconsin Coastal Management Program through a grant to the Friends of Cedarburg Bog, the Wisconsin Geological and Natural History Survey, Wisconsin Department of Natural Resources, Ozaukee and Washington Counties, and University of Wisconsin-Milwaukee.

Atlas of North American Amphibians

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This is a book project with the University of California Press. The Atlas of North American Amphibians will present detailed distribution maps and brief species descriptions of each of the 298 currently recognized amphibian species in the United States and Canada. Initial copy was delivered to the Press in 2012. Funded by Indiana University School of Medicine.

Condition Effects on Female Mate Choice in an Anuran

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Understanding the mechanisms behind female mate choice is critical in developing a holistic framework from which to assess its impacts on sexual selection. Many mechanisms affecting mate choice variation are currently being explored related to life history traits or prior experience. In a system in which mate choice is costly or requires great investment it could be argued that female condition is the most important. If variation in condition is linked to variation in mate choice, then this can be a source for maintenance in variation in strength and direction of sexual selection and ultimately variation in male traits.

Using Gray treefrogs, *Hyla versicolor*, I designed two experiments to quantify the effects of condition on female mate choice, one using the natural variation in female condition and a second manipulating female condition. The first experiment simply assessed preferences of females in their natural state. For the second experiment, 60 females from experiment 1 were randomly assigned to food treatments designed to alter their condition and retested to relate manipulated condition to any changes in female choice. The 2009 field season produced data for 92 females assessing natural variation in condition with mate choice. Experiment 2 gathered data for 11 females assessing preferences relative to manipulated body conditions, in which better body conditions correlated to the high food treatment. Data analysis is continuing. M.S. Thesis research, Dr. Gerlinde Höbel, Major Professor.

Using Geolocators to Map the Migration and Locate the Winter Range of Migratory Tree Swallows

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The tracking of migratory birds has generally been limited to larger birds because of the weight restrictions of satellite tags. However, with the introduction of light-logging geolocators, scientists can now attach devices weighing less than 1 gram to small migratory birds to track their migration paths, stopover sites, and wintering areas. Geolocators are small devices that log light levels every few minutes throughout the year. The data can be analyzed to estimate the location of the individual wearing such a device: sunrise and sunset times are used to estimate the longitude, and day length is used to estimate the latitude. Such technology has been used to track Wood Thrushes, Purple Martins, and many species of shorebirds.

In the summer of 2011, we attached light-level geolocators to 58 Tree Swallows at the UWM Field Station. In the summer of 2012, we returned to the Field Station to retrieve the devices from the birds. We retrieved 15 geolocators from the birds that returned. We analyzed the data from these devices using BAS Track and GeoLight software. Some of the devices failed to log light levels for the entire year. After leaving Wisconsin in October, the birds travelled to their main overwintering sites. One bird wintered along the coast of Delaware, eight birds wintered in Florida, the Bahamas, and Cuba, and one bird wintered as far south as southern Nicaragua. Further details of the results will be presented in a publication in 2013. This study was part of a much larger project with multiple researchers that attached geolocators to Tree Swallows across their breeding range.

Tree swallow with geolocater

Genetic Studies of the Hine's Emerald Dragonfly Population at Cedarburg Bog

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Previous studies have examined the mitochondrial DNA of Hine's Emerald Dragonfly from populations along the Des Plaines River, Illinois, and from wetlands in Door County, Wisconsin. Only one genetic variant was recovered from several individuals sampled from Door County, and the Door County variant was not found in Illinois, despite the fact that this latter population contained a number of other variants. The population of Hine's Emerald at Cedarburg Bog is located between those in Door County and the Des Plaines River valley. Genetic analysis of a single specimen recovered from the Cedarburg Bog area found the same haplotype as seen in Door County, suggesting possible recent contact between these areas. Four additional samples collected as 'road kill' specimens from the area of the field station were analyzed in 2010. Three samples had the same Door County variant. The fourth sample had a genetic variant matching a museum specimen from a site in Ohio where Hine's Emerald is now extirpated. These results support the connection between Cedarburg Bog area and Door County and also indicate an historic connection to populations in Ohio that was likely disrupted by modifications to the landscape. Including additional samples from Cedarburg Bog area is likely to improve our knowledge of genetic diversity and dispersal patterns of Hine's Emerald Dragonfly in this region.

Developing qPCR Primers for Fatty Acid Degrading Bacteria

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Fatty acid degrading bacteria are very important functional components of anaerobic habitats. They break down fatty acids (e.g., butyrate, propionate and acetate) producing H_2, CO_2, and acetate which are utilized by methanogens, sulfate reducing bacteria and homoacetogens. Molecular tools capable of monitoring fatty acid degrading bacteria are needed to accurately assess their presence and abundance in anaerobic habitats. We are comparing a wide range of anaerobic habitats for the presence and abundance of fatty acid degrading bacteria and relating these characteristics between communities. As part of this study, we collected samples from the Cedarburg Bog at the UWM Field Station from the bottom of open water in the middle of the bog and from the bottom of one of the ponds at the edge of the bog. Due to drought during 2012 the pond was empty of water, however, the sample collected from the pond location smelled of sulfide, indicating an anaerobic habitat. DNA was extracted from all samples and subjected to PCR amplification. To date, we have tested PCR primers developed for butyrate degrading bacteria for amplification using DNA from the samples and they were below detection. We are currently testing primers for the presence of propionate degrading bacteria on the same samples.

Long-term Monitoring of Bat Activity and Temperature at the Neda Mine Bat Hibernaculum

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The Neda Mine, an abandoned iron mine located near Iron Ridge in Dodge Co., supports about 150,000 bats each winter, making it among the largest hibernacula in the midwest. The mine is used primarily by little brown bats (*Myotis lucifugus*), with Northern Bats (*M. septentrionalis*), Eastern Pipistrelles (*Pipistrellus subflavus*), and Big Brown Bats (*Eptesicus fuscus*) found in smaller numbers. We have been monitoring bat activity at the mine since 2001 using an infra-red photo beam-break detection system that records the number of bats entering and leaving the mine on a 5-minute interval 365 days per year. We have been collecting temperature data since 1996 using 18 battery-powered temperature dataloggers spread within the mine and 2 dataloggers outside. We are also monitoring airflow in the mine. We are currently using these data to examine trends over time in winter temperatures in the mine, and the phenology of bat emergence in spring. We are currently collecting data on nocturnal aerial insect

abundance at the Field Station to determine the relationship between night-time temperatures in spring and insect activity. These data will help us to interpret patterns of bat activity in the spring by providing information on how their aerial insect prey is affected by spring temperatures.

Bat Monitoring at the Cedarburg Bog – UW-Milwaukee Field Station

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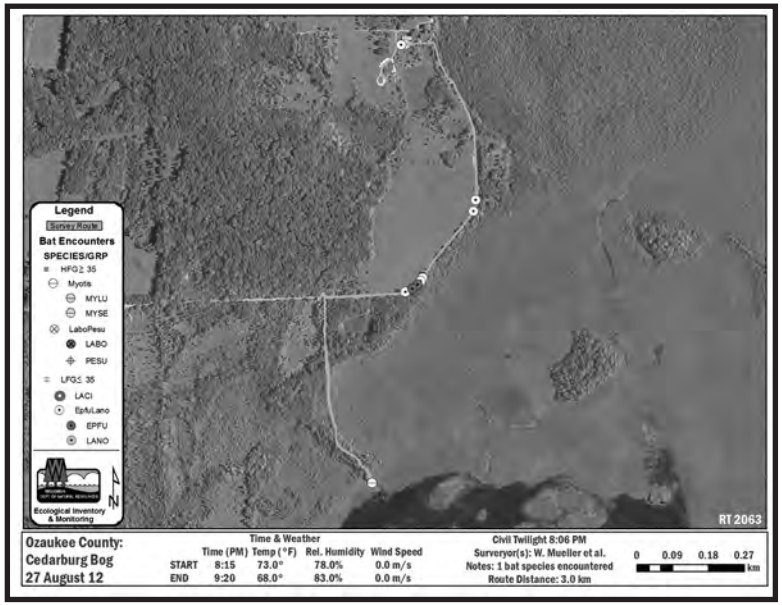
The Wisconsin Bat Monitoring Program uses volunteers to gather data on bats in a variety of Wisconsin locations. As part of this Monitoring Program, a demonstration "bat walk" for Friends of Cedarburg Bog monitored bats along the edge of Blue Goose and St. Augustine Roads, and trails south to Mud Lake, on August 27, 2012. The hand-held ANABAT device records bat echolocation/vocalizations and the date and time of each bat encounter. Combined with a global positioning system (GPS), the detector records the position (latitude & longitude) of each bat passing the surveyor, mapping the route traveled during the survey. Attached to the detector, a personal data assistant (PDA) then provides real-time tracking of the bat as it echolocates (as a change in frequency over time), and stores the data for later analysis by the Wisconsin Department of Natural Resources. Most encounters produce a record that can be identified to a species, but some are narrowed down only to a "species group". During the survey conducted on August 27th, we recorded 9 detections including Big brown bat (*Eptesicus fuscus*), Silver-haired bat (*Lasionycteris noctivagans*) species group and a Myotis species.



Mud Lake Migration Point Counts

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Mud Lake is 245 acres in size and is the largest lake within the Cedarburg Bog. Point counts were conducted weekly in 2012 by canoe and/or kayak on Mud Lake during spring migration (March 13-June 4) to determine the bird species using the lake and surrounding habitats. All bird species seen or heard were counted at six points around the Lake. Birds observed while walking to and from the canoe landing and paddling between points were also counted. Playback for secretive wetland species was used five times and the Least bittern, Sora and Virginia rail responded. In fall, low water levels made the lake inaccessible by boat, so counts were conducted at two of the six points from land (Sept. 7- Oct. 19). We documented 151 bird species that used the Lake and surrounding habitats during spring and fall migration.

Green Heron

A number of species new to the Mud Lake area were observed during the counts in 2012: Great egret, Black and Forster's tern, Black-crowned Night heron, Trumpeter swan, Eastern screech owl, Connecticut warbler and Cackling goose. Mud Lake was more mud than lake in the fall of 2012, which provided good shorebird habitat and good numbers of shorebirds. Regular sightings of the Northern harrier and Least bittern suggest possible breeding of these species in the area. Several Willow flycatcher pairs were confirmed as breeding on two Mud Lake islands. Frequent sightings of several immature Bald eagles from spring through fall in both 2011 and 2012 suggest the potential for eagles breeding in or near the Bog in the future.

Yellow Legs

The counts demonstrated that Mud Lake is an important spring migration staging area for waterfowl, cranes and rails. The Lake and surrounding habitats provided habitat during spring and fall migration for a number of bird species of conservation concern. Fifty-two species of birds (34.4 % of the total) are listed as being at risk in national, regional or Wisconsin conservation plans. Forty species are listed as being of conservation concern in national or regional (U.S. / North American) Landbird, Shorebird, Waterbird or Waterfowl Conservation Plans. These species included Pied-billed and Horned grebe, American and Least bittern, Black-crowned night- heron, Cackling goose, Trumpeter swan, Wood duck, Gadwall, American widgeon, American black duck,

Mallard, Blue-winged teal, Northern shoveler, Northern pintail, Green-winged teal, Canvasback, Redhead, Ring-necked duck, Greater and Lesser scaup, Bufflehead, Common goldeneye, Virginia rail, Sora, Killdeer, Greater and Lesser yellowlegs, Solitary and Least sandpiper, Wilson's snipe, American woodcock, Forster's and Black tern, Olive-sided and Willow flycatcher, Blue-winged, Bay-breasted and Canada warbler and Rusty blackbird. Twenty-nine species are listed as Bird Species of Greatest Conservation Need in Wisconsin. Seventeen species are listed as being at risk in both national/regional and state conservation plans.

Larry Hopwood also assisted with the migration counts in 2012. The Mud Lake migration counts will continue in 2013.

Pileated woddpecker

Black capped chickadee

Grebe

Canvasback

The Role of the Social Environment in Influencing Phenotypic Variation in Individuals

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My objective is to test the hypothesis that genetic variation in the social environment influences the patterns of phenotypic variation of individuals. Using *Enchenopa binotata* treehoppers (Hemiptera: Membracidae), I am addressing two relevant sources of selection of the social environment on their phenotypes: interactions with conspecifics and interactions with their host plant *Viburnum lentago* (Caprifoliaceae). Specifically, I am looking at how genetic variation in one's social neighbors and genetic variation in the host plant influence phenotypic variation in male mating signals and female preferences for male signals. These fitness-related traits have played an important role in speciation and diversification of this clade of plant-feeding insects, and have important evolutionary implications moving forward. To this end, I collected 100 mated females and suckers from clonal patches of *V. lentago* host plants at the Field Station (20 clone patches, 5 suckers per patch). The treehoppers and host plants were established to address four questions: 1) how phenotypic variation in male signals and female preferences is influenced by genetic variation in the host plant, 2) how male signals and female preferences covary across genetic variation in host plants, 3) how phenotypic variation of male signals and female preferences is influenced by genetic variation in their social neighbors, and 4) how male signals and female preferences covary with genetic variation in social neighbors. The mated females collected are being used to establish full-sibling families for these experiments.

Preliminary results indicate several important findings. First, female mate preferences of unrelated individuals are influenced by the family with which they develop. Second, both male signals and female preferences are influenced by the host plant that they develop on. These results highlight the

Enchenopa binotata treehoppers

potential of these two aspects of the social environment to maintain genetic variation in populations, and also the potential for the onset of divergence and subsequent speciation. Given these promising results, more females and plants will be collected in the upcoming year (2013) to continue this research project. Ph.D. Dissertation research, Rafael Rodríguez, Major Professor. Funded by a Ruth Walker Award and a James D. Anthony Award.

Cedarburg Bog Basin Topography

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The 886 ha (2,190 acre) Cedarburg Bog basin has irregular contours that reflect its kettle moraine/end moraine glacial history and the time it spent as a glacial lake. There are nine glacial till islands in the bog and a maximum depth of peat and lake sediments of at least 15 m. Between these two extremes the basin depth varies at a relatively fine scale. In the late 1960s Grittinger sampled the depth of the basin along six transects. Since that time we have added more basin depth soundings, taken by inserting a metal rod into the sediments until we reach refusal in either heavy clay or sand and gravel. We now have a sample of 611 measurements of basin depth, however because of the scale of the basin topography, and the accuracy with which we seek to map the bottom, this sample is still inadequate to draw a reasonable contour map for some large parts of the wetland basin. We continue to collect measurements of the basin depth to improve the accuracy of the basin contour map. Undergraduate Independent study project for S. Appel.

Conservation of the Southeastern Wisconsin Tamarack Swamp: Loss, Persistence, and Restoration

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Larix laricina (Du Roi) K. Koch is an important tree species in the forested wetlands of Southeastern Wisconsin and, with a Coefficient of Conservatism of 8, its presence is an indicator of some of the highest quality wetlands in the region. Tamarack is near the southern limit of its range in southeastern Wisconsin, and has been extirpated from a large number of swamps. The overall goal of this thesis is to understand the conservation status of tamarack in the region relative to pre-settlement ecology, and to develop restoration strategies and techniques. The objectives are threefold: 1) to describe the historic distribution of tamarack swamps in southeastern Wisconsin and compare that to the current distribution and determine tamarack loss; 2) to describe the factors correlated with tamarack persistence over time; and, 3) to compare restoration site preparation techniques for establishment of tamarack seedlings.

I conducted two landscape-scale analyses of the past and current distribution of tamarack in southeastern Wisconsin and the factors that correlate with long-term persistence of tamarack swamps in the Southern Glacial Plains Ecological Landscape (SGP) in Wisconsin using pre-settlement data from the General Land Office Public Land Surveys (1830s-1860s), current Natural Resources Conservation Service maps of hydric soils, current Wisconsin Wetland Inventory, and the Southeastern Wisconsin Regional Planning Commission Land Use data from 2000. Almost 85% of the tamarack swamp area in southeastern Wisconsin has been lost since pre-settlement times, most of it by conversion to other plant communities; only 19,400 ha of the estimated 125,704 hectares remain since the mid-1800s. Area of mineral and organic hydric soils is nearly equal in the 764,880 ha study area, which is defined as the Southern Glacial Plains area that had tamarack (SGP-T). However, pre-settlement tamarack was much more common on organic (present on 91% of area) than on mineral (26%) hydric soils. While I estimated that 38% of the wetland total area has been lost from the (SGP-T), there has been a disproportionate loss of mineral soil wetland area (62%) compared to organic soil wetlands (17%), and tamarack has been disproportionately lost from the mineral soil wetlands that remain, so that only 4.5% of the original mineral-soil tamarack swamp persists today compared to 17% of the original organic-soil tamarack.

On average the pre-settlement Original Tamarack Swamps (OTS) where tamarack persists today have 17% more organic soil area, were almost twice as large, and had 20% more complexity of shape compared to those OTS from which tamarack has been extirpated. Using Southeastern Wisconsin Regional Planning Commission land use maps, I found that land use surrounding wetlands also was correlated with the persistence of tamarack swamp. OTS that have lost tamarack had, on average, more urban land uses (development and transportation), and less woodland area in their surrounding 800 m buffer. Surprisingly, OTS where tamarack persists had a significantly higher percentage of agricultural land use in their surrounding buffer, probably because a higher percentage of agriculture reflected lower percentages of development and transportation land uses. A logistic regression model using both wetland characteristics and surrounding land use correctly predicted tamarack persistence in 70% of wetlands, and tamarack loss in 77% of the OTS, without any information on direct historical disturbances to the wetland itself.

To develop practical methods for tamarack regeneration in southeastern Wisconsin, I conducted a field experiment to compare tamarack germination and seedling survival in five seedbed preparation treatments applied before direct seeding of tamarack in three locations in the Cedarburg Bog Wisconsin State Natural Area. I also compared these direct seeding methods to planting of bare-root tamarack seedlings. Complete removal of woody vegetation overstory (shading) was required for successful establishment of tamarack either from seed or with bare-root seedlings. Good stocking rates of seedlings were achieved with most treatments after removal of the shading tree and shrub canopy. Treatments that further reduced competition and increased establishment success were burning, herbicide application, and raking (soil disturbance). Planted 2-3 year-old, bare-root tamarack seedlings also required a cleared, un-shaded, habitat for high survival and planted seedlings were found to have a high survival rate in a wider range of hydrologic conditions than seedlings produced by direct seeding methods.

The landscape scale analyses will help identify and prioritize locations for tamarack restoration and reforestation in the SGP while the regeneration trials will provide practical methods for tamarack restoration on both small and large scales. MS Thesis completed 2012, James Reinartz, Major Professor. Funded by the Wisconsin State Wildlife Grants Program.

Long-term Dynamics of the Benedict Prairie Communities

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Benedict Prairie has a host of historical data on plant and insect community composition, collected starting in the early 1950s by Phil Whitford at UW - Milwaukee and continuing through the early 2000s. The Benedict Prairie data are particularly useful for studying change because it has been sampled at semi-regular intervals, including Linda Curtis' data from the mid-1970s. Curtis' data contains spatially explicit information, which will allow students to examine within-site variation and thus how community composition and change depends on gradients in soil moisture availability. This work has generated interest in revisiting all of Whitford's original prairie sites (61 in total, all in SE Wisconsin), so that we can compare the effects of management vs. no management on long-term changes in prairie community composition. Benedict Prairie has evolved into a key outdoor laboratory for students at UW – Parkside. It is frequently used for observational studies as well as providing a site for studying trophic interactions between Canada goldenrod (*Solidago canadensis)*, a gall forming fly (*Eurosta solidaginis*) and host gall fly parasitoids (*Eurytoma spp*.). The goal of this project is to examine how land-use history and landscape features influence the trophic interactions in this host/parasite/parasitoid system.

Bridging Spatial Scales Using Phenological Measurements to Improve Understanding of Autumn Atmosphere-Biosphere Interactions

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Enhancing the accuracy of energy/carbon flux estimates at all scales is a critical part of improving understanding of the interactions between land surface biospheric processes and global climate change. Current approaches that scale between regional estimates with data from remote sensing, eddy covariance flux, and intensive plant- and stand-level flux measurements assume estimates from these extremely small areas are representative of larger regions. The timing of leaf senescence (coloring and subsequent fall; i.e., phenology) during autumn has large impacts on lower atmospheric energy-mass exchange through differential carbon assimilation and transpiration totals across the landscape, which are equal to or greater than those of spring phenology. However, spatial variations in autumn phenological timing at the community level have not been systematically measured and analyzed, and underlying environmental drivers are not well understood. If large, autumn leaf senescence variations may reflect gradients in plant growth that could foster systematic errors in seasonal fluxes of equal or greater magnitude than those during earlier portions of the growing season. Thus, autumn phenological data collected in a spatially explicit manner offer considerable opportunities for gauging landscape-level spatial variations crucial for accurate scaling-up of flux measurements to larger areas or downscaling regional-scale atmospheric circulation models. In this project, spatial variability of autumn phenological data will be measured and analyzed at the community level, compared to microclimatic and remote sensing measurements, and used as the basis for regional-scale multi-species phenological models, which could contribute to increased accuracy of energy/carbon flux estimates across large areas.

As part of this project, 108 evenly distributed trees have been marked in Downer Woods (on the UW-Milwaukee campus) and are being phenological observed in autumn (since 2007). In addition, automatic air and soil temperature measurements are being collected at several locations to support analyses of these phenological measurements. These measurements will also be compared to data being collected on at least one similar species (*Tilia americana*, Basswood) at both the UWM Field Station and at the primary study site of this project near Park Falls, WI. Funded by National Science Foundation.

An Urban Cooper's Hawk Nesting Study in the Metropolitan Milwaukee Area

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The objectives of this study are to gather baseline data on the reproductive success of Cooper's Hawks (*Accipiter cooperii*) in the urban metropolitan Milwaukee area, to describe urban nesting habitat, and to compare these data with other Cooper's Hawk studies in Wisconsin. Long-term objectives are to determine Cooper's Hawk nest site fidelity, breeding population mortality and recruitment, population growth trends, immigration and emigration patterns, and natal dispersal patterns for the same urban population. For the 2012 Cooper's Hawk breeding pair at Downer Woods (UW-Milwaukee), both the first nesting attempt as well as a second nesting attempt failed; the nesting attempts were checked six times between 9 May and 1 August 2012. While

the adult female did have a black colored leg band (the same color as in previous years), the alphanumeric code on the band was obscured by vegetation while viewing and could not be determined. The adult male was not able to be identified by the alphanumeric colored leg band. Excessively hot and dry conditions during the incubation period were noted. This project was supported, in part, through the Wisconsin Society for Ornithology (WSO) Small Grants Program.

Effects of Different Bumble Bee Species on Reproductive Success and Mating Patterns in *Mimulus ringens*

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Most flowering plants are pollinated by several animal species. Interactions between pollinators and recipient flowers may influence the quantity of pollen deposited on stigmas and resulting seed production. In addition, pollinators may differ in foraging behaviors that influence two measures of the quality of pollination: the proportion of self and outcross pollen, and the number of outcross pollen donors. It has long been assumed that visits by different bumble bee species (*Bombus*) are equivalent in amount and quality of pollen deposited. However, these bee species often vary considerably in size and foraging behavior. We hypothesize that individual bee species may not be equivalent in their contributions to plant reproductive success. By allowing local populations to forage through replicate arrays of monkeyflower (*Mimulus ringens*), we are currently measuring the differential effects closely related bumble bee species have on seed set, pollen deposition and pollen removal. MS Thesis Research, Dr. Jeff Karron, Advisor.

White-nose Syndrome Surveillance in Wisconsin

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White-nose syndrome (WNS) is a devastating cave-bat disease caused by the fungal pathogen *Geomyces destructans*. Since its discovery in 2006 in New York, the disease has spread to 19 states and four Canadian provinces and has killed 90 to 100 percent of the bats in the hibernacula it contaminates. The U.S. Fish & Wildlife Service estimates that 5.7 million to 6.7 million bats have already died from the disease. Voracious insect eaters, bats keep mosquitoes and crop and forest pests in check – a service one recent national study estimated as worth $658 million to $1.5 billion alone for Wisconsin's agricultural industry.

Monitoring Wisconsin's bat populations is crucial for WNS management for two reasons: establishment of pre-WNS baseline data and early disease detection. Baseline data on population densities, hibernacula locations, movement patterns, and health is necessary for ongoing research on WNS. WDNR field crews have surveyed more than 90% of the Wisconsin's 120 potential hibernacula, recording information on species, estimated number of bats present, temperature, and general site conditions. This information helps determine where *Geomyces destructans* could survive or spread, prioritize future monitoring, and identify potential hibernacula for a recovering bat population. Early WNS detection gives managers and researchers the earliest opportunity to develop and experiment with control methods focused on stopping or slowing the spread of the disease. During the Department of Natural Resources 2012 WNS surveillance season, the bat field crew investigated 117 underground hibernacula throughout the state. All known sites were checked. The largest three hibernacula in the state include Maiden Rock Mine, Neda Mine State Natural Area, and Bay City Mine. These three locations have approximately the same number of bats and hold the largest proportion (97%) of Wisconsin's bat population. No signs of the disease causing fungus or the disease itself were found during the 2012 surveillance season. Funded by US Fish & Wildlife Service, Wisconsin Department of Natural Resources, and private donations.

A General Survey of Wisconsin's Beetle Diversity (Insecta: Coleoptera)

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During the 13 week period of 30 May to 31 August 2012, two Malaise traps and four Lindgren funnel traps were run at the UWM Field Station, with samples collected weekly. One Malaise and all Lindgren traps were located just inside the old growth beech-maple forest west-southwest of the Station; one Malaise was set in a prairie restoration (43.38885°N/-88.02678°W). The 2012 survey continued a sampling study begun in 2011. Of 103 beetle families known or presumed to inhabit Wisconsin, this ongoing survey has now established the presence of 51 families at the sampled Station sites. The annotated list documents approximately 127 species as well as 16 new county records and one new state record. This was the first year an adult of the emerald ash-borer, *Agrilus planipennis* Fairmaire, was intercepted in a Malaise trap (prairie). The year (2012) depicted a very unusual phenology for most beetle species, with many mid- to late summer species having completed their adult flight period long before the 2012 sampling end date. Several traditionally early-season species hypothesized to be represented in the forest fauna were not encountered, at all. I anticipate beginning the 2013 survey much earlier (likely early April). The current plan is to focus, once again during the 2013 field season, in the old growth beech-maple forest.

Recent Publications and Theses

Recent Publications Resulting from Field Station Projects

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Redell, David N. 2005. Behavioral ecology of bats using the Neda Mine hibernaculum. M.S. thesis.

Garvin, Julia C. 2006. Male ornaments, extra-pair mating, and immunocompetence in the common yellowthroat. Ph.D dissertation.

Bott, Terry. 2007. Morphological diversity of the northern pitcher plant (*Sarracenia purpurea* L.) in two contrasting wetlands. M.S. thesis.

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Methods of Description workshop participants doing field work.

Cooperation with Other Groups and Agencies

Service to the local community, and to the state-wide community of individuals, groups, and organizations engaged in natural area study and preservation is a major part of the Field Station's mission. To the extent that our staff has time available, we provide natural area consulting services to the community. The demand for these services exceeds our capacity to help, but we feel that these cooperative efforts are a very important part of our mission.

1. **Friends of the Cedarburg Bog.** The Field Station cooperates with and helps to support this non-profit organization that has a mission to initiate and support activities that will enhance the natural history, public appreciation, and scientific study of Cedarburg Bog in cooperation with the Wisconsin DNR and UWM.

2. **Department of Natural Resources**. The Station continued its wide range of planning and management activities in conjunction with the DNR. These activities include the day-to-day surveillance of the Cedarburg Bog performed by Station staff and some assistance with maintenance activities such as snowplowing.

3. **Natural Areas Preservation Council.** The Station participates in the State Natural Areas program, since the Station owns and manages five properties that have State Natural Areas status.

4. **Ozaukee Washington Land Trust.** The Land Trust is a non-profit, land conservancy for Ozaukee and Washington Counties. The Field Station helps to support the organization's activities in various ways. Jim Reinartz served on the Conservation and Stewardship Committees and on the management committee for their Fairy Chasm property.

5. **Invasive Plants Association of Wisconsin.** This non-profit organization works to stop the spread of invasive plants in Wisconsin. Reinartz serves on the Board of Directors and is editor of the IPAW newsletter, "Plants out of Place".

6. **Riveredge Nature Center**. The Field Station cooperates with RNC on a wide range of programs.

7. **Regional School Systems.** Advanced biology classes from several high schools in the region (Milwaukee, Ozaukee, and Washington counties) use the Field Station for ecology field classes.

8. **National Oceanic and Atmospheric Administration** – Milwaukee Office Weather records are provided monthly and frost and snow depth data are collected in winter.

9. **Organization of Biological Field Stations**. The Station is an active member of this national organization and cooperates in the exchange of information on programs.

10. **Wisconsin Department of Transportation.** The Station raises beetles for biological control of purple loosestrife for WDOT.

11. **Urban Ecology Center—Milwaukee.** G. Meyer serves on the Citzen Science Advisory Council.

12. **U.S. Fish and Wildlife Service.** G. Meyer provides support for monitoring of the federally-endangered Hine's emerald dragonfly (Somatochlora hineana).

13. **Wisconsin Task Force on Invasive Species.** Reinartz serves on the task force and chairs the Science and Research Subcommittee of the task force.

14. **Southeastern Wisconsin Invasive Species Consortium (SEWISC)**. Reinartz serves on the Board of Directors and as Treasurer for the organization.

15. **Ozaukee Treasures Network**. The Field Station is cooperating with this consortium of over 30 environmental organizations to promote conservation in Ozaukee County.

16. **Wisconsin Phenological Society.** G. Meyer serves on the Board of Directors.

17. **Phenology 2012 Conference**. G. Meyer served on the organizing committee for the second interdisciplinary international conference on phenology, held in Milwaukee in 2012.

2012 Natural History Workshops

This is a series of intensive workshops on specialized topics which provide a continuing education opportunity and a meeting place for biologists. Ten workshop topics were offered in 2012. Most of these workshops were filled to the capacity of 20 people.

Workshop	Instructor	Date
Ecology and Physiology of Plants in Winter: Surviving the Big Chill	James Reinartz	January 6 & 7
Writing About the Natural World	Mary Linton	April 20 & 21
Field Herpetology: Identification of Wisconsin Amphibians and Reptiles	Josh Kapfer	June 1 & 2
Sedges: Identification and Ecology	Anton Reznicek	June 15 & 16
Vegetation of Wisconsin	James Reinartz and Marc White	June 18 - 23
Methods for Description of Vegetation	James Reinartz	July 16 -21
Introduction to Insects	Gretchen Meyer and Robert Clare	July 27 & 28
Native Mussels of Wisconsin, an Amazing Resource	Lisie Kitchel	August 10 & 11
Spiders: Identification & Ecology	Michael Draney	August 24 & 25
Techniques in Mammal Censusing	Christopher Yahnke	September 15 & 16

Class and Group Use

Winter - Spring 2012

	Number of Student Hours
Ecology and Physiology of Plants in Winter Workshop	360
Creative Writing Workshop	360
Winter Ecology Hike and Friends Chili Dinner	540
Friends of Cedarburg Bog – Owl-prowl hike	60
Friends of Cedarburg Bog – Owl-prowl hike	50
Friends of Cedarburg Bog – Spring frogs and woodcock	80
Friends of Cedarburg Bog – Ecology of frogs walk	50
Friends of Cedarburg Bog – The Bog in Spring	60
Friends of Cedarburg Bog – Ecology of the Bog – North	70
Friends of Cedarburg Bog – Bat survey	40
Friends of Cedarburg Bog – Spring bird walk	60
Friends of Cedarburg Bog – Meetings	90
Field Station Garlic Mustard Search/Pull	30
UWM Innovation Park – Monarch trail tour	80
Riveredge Nature Center Master Naturalists Training	70
Benedict Prairie – Prairie work days	90
Benedict Prairie – prairie Enthusiasts – Prairie planning	20
Wisconsin Phenology Club - Phenology program tour	50
Milwaukee Area Technical College – Horticulture – bog tour	80
Milwaukee Area Technical College – Natural Landscaping	50
UW Oshkosh – Environmental class field trip	380
UWM – Conservation and Environmental Science Picnic	80
UWM – Geophysics – Mud lake exploration	60
UWM – Plant Systematics	70
TOTAL	2,880

Summer 2012

Field Herpetology Workshop	360
Sedges: Identification and Ecology Workshop	360
Vegetation of Wisconsin Workshop	1,240
Methods for Description of Vegetation Workshop	900
Introduction to Insects Workshop	140
Native Mussels of Wisconsin Workshop	380
Spiders: Identification and Ecology Workshop	360
Friends of Cedarburg Bog – Animal Ecology class	70
Friends of Cedarburg Bog – Summer Solstice Walk	60
Friends of Cedarburg Bog – Wild foods workshop	160
Friends of Cedarburg Bog – Bat survey / walk	40
Friends of Cedarburg Bog – meetings	70
Treasures of Oz / FOCB – Bog Event	90
Riveredge Nature Center – Teacher Naturalist class	40
Urban Ecology Center – Intern Field Trip	30
Mushroom foray	20
UWM Moth Survey	30
UWM Neda Mine tour	20
Wisconsin Dragonfly Society field trip	60
Wisconsin DNR Bog Tour	10
Carroll University- Field Botany	90
TOTAL	4,530

Fall 2012

Techniques in Mammal Censusing Workshop	360
Friends of Cedarburg Bog – Annual Meeting & potluck	140
Friends of Cedarburg Bog – Northern Cross stargazing event	120
Friends of Cedarburg Bog – Fall migrant bird hike	80
Friends of Cedarburg Bog – Owl Prowl	70
Friends of Cedarburg Bog – meetings	80
Kettle Moraine Lutheran High School	60
Ozaukee Treasures Network tour	20
Ozaukee Washington Land Trust – AmeriCorps tour	40
Riveredge Nature Center – Christmas Bird Count	60
WDNR / State Natural Areas tour of Bog	30
UWM – International Phenology Conference field trip	60
Alverno College – Wetland Ecology	50
University of Illinois-Chicago– Ecology field trip	820
UW – Platteville – Ecology field trip	240
UW – Whitewater – Ecology class	40
UWM – PantherVision project	20
UWM – Conservation and Environmental Science	400
UWM – Geography – Soils	180
UWM – Geology – Hydrogeology	280
TOTAL	3,150

TOTAL 2012 Class & Group Use Hours **10,560**

Friends of Cedarburg Bog Board President, Carl Schwartz leading a hike to Watts Lake at the 2012 Treasures of Oz event

Meteorological Data for 2012

This yearly summary is modeled, where possible, after the summaries provided by the National Oceanic and Atmospheric Administration (NOAA). Some differences between the two reports reflect differences in available equipment. Records for the Field Station are reported in degrees Celsius and in other metric measures. In addition, growing degree-days at 5° and 10°C, (see below for description) were substituted for the heating and cooling degree-days used by NOAA. The variables reported in the summaries are defined as follows:

Temperature

Average Daily Maximum: Monthly mean of the 30-min period in each day with the highest mean temperature.

Average Daily Minimum: Monthly mean of the 30-min period in each day with the lowest mean temperature.

Daily Average: Monthly mean of all 30-min means. (NOAA uses the midpoint between the daily minimum and maximum for this measure.)

Highest(Date): Highest 30-min mean temperature. (Day of month with highest temperature.)

Lowest(Date): Lowest 30-min mean temperature. (Day of month with lowest temperature.)

Degree Days

Sum at 5°: Sum of the number of degrees by which the daily average temperatures exceeded 5° C.

Sum at 10°: Sum of the number of degrees by which the daily average temperature exceeded 10° C.

Radiation (kW/m^2)

Mean: Mean of all 30-min means in the month.

Maximum: Maximum 30-min mean during the month.

Relative Humidity

Monthly mean of the 30-min means for each quarter of the day.

Number of Days

Precipitation of 0.25 mm or more

Temperature-Maximum

32° and above: Number of days with a maximum 30-min mean temperature of 32° C or above.

0° and below: Number of days with a maximum 30-min mean temperature of 0° C or below.

Temperature-Minimum

0° and below: Number of days with a minimum 30-min mean temperature of 0° C or below.

-18° and below: Number of days with a minimum 30-min mean temperature of -18° C or below.

Mean Pressure (mbars)

Mean of all 30-min means in the month.

Precipitation (mm)

Total: Sum of all precipitation during the month.

Greatest (24 hrs) (Date): Total precipitation on the day with the most precipitation and the date on which it occurred.

Wind

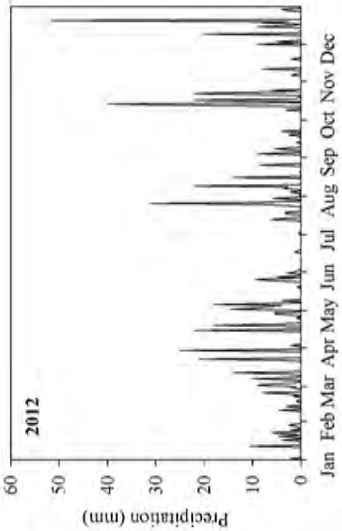
Mean Speed (m/s): Monthly mean of all 30-min means

Maximum Speed (m/s): Highest mean wind speed during a 30-min period.

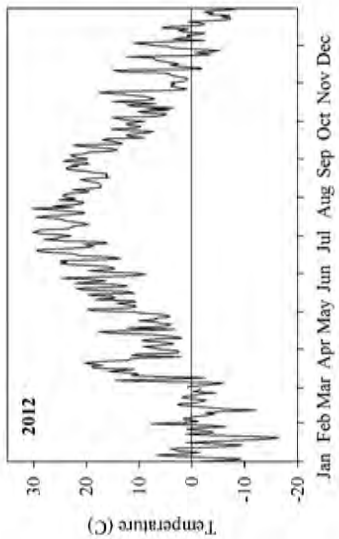
The Field Station can provide weather data in electronic format; datasets go back to 1989. Please contact us if you would like to receive the weather data.

Meteorological Data for 2012	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
Temperature (C°)												
Average Daily Maximum	1.3	2.6	13.7	12.2	21.1	27.0	30.5	26.3	21.8	13.6	8.1	2.8
Average Daily Minimum	-8.1	-5.8	3.3	1.5	9.2	13.3	17.8	14.2	8.3	3.3	-1.6	-4.2
Daily Average	-3.1	-1.5	8.6	7.2	15.6	20.7	24.2	20.3	14.9	8.5	3.1	-0.5
Highest (Date)	12.9 (11)	9.3 (29)	28.9 (21)	23.0 (15)	31.5 (20)	34.2 (28)	38.5 (5)	31.7 (30)	29.9 (12)	23.1 (4)	18.6 (11)	16.8 (3)
Lowest (Date)	-20.7 (20)	-15.3 (11)	-14.4 (5)	-3.3 (7)	2.1 (10)	5.2 (2)	10.6 (11)	7.2 (18)	-2.1 (19)	-3.7 (27)	-10.8 (27)	-13.4 (31)
Degree Days												
Sum at 5°	4.5	0.0	167.2	77.3	327.8	471.6	596.1	475.3	298.3	123.6	31.5	13.9
Sum at 10°	0.0	0.0	73.9	16.0	174.0	321.6	441.1	320.3	154.3	36.9	10.6	1.1
Radiation (kW/m^2)												
Mean	NA[1]	0.11	0.15	0.21	0.25	0.32	0.28	0.23	0.19	0.10	0.07	0.04
Maximum	NA	0.68	0.85	1.01	1.04	1.11	1.11	0.97	0.88	0.72	0.55	0.46
Relative Humidity (%)												
Hour 00-06 mean	83.2	85.2	84.2	84.5	82.9	82.5	90.8	90.1	89.6	84.7	83.0	89.4
Hour 06-12 mean	78.4	79.6	74.1	64.5	62.5	56.4	64.8	68.5	66.8	72.9	76.1	86.4
Hour 12-18 mean	68.8	67.8	63.4	54.3	54.1	45.3	53.7	57.4	54.0	65.0	66.0	81.8
Hour 18-24 mean	79.1	80.3	78.0	74.6	73.2	68.3	78.5	87.0	83.9	80.3	82.4	89.6
Number of Days												
Precip. 0.25mm or more	11	8	11	9	12	4	11	10	8	11	4	11
Max Temp 32º and above	0	0	0	0	0	7	9	0	0	0	0	0
Max Temp 0º and below	13	5	2	0	0	0	0	0	0	0	3	14
Min Temp 0º and below	29	27	9	10	0	0	0	0	1	7	23	24
Min Temp -18º and below	3	0	0	0	0	0	0	0	0	0	0	0
Pressure (mbars)												
Mean	1012.89	1017.18	1014.90	1016.29	1015.00	1013.98	1015.41	1015.69	1016.44	1011.39	1020.23	1014.42
Precipitation (mm)												
Total	35.5	36.0	96.0	60.1	81.1	3.8	70.5	54.0	25.1	142.3	13.0	115.0
Greatest (24 hrs) (Date)	10.5 (12)	13.0 (29)	25.0 (30)	22.0 (15)	18.0 (6)	1.3 (17)	31.2 (26)	22.0 (9)	9.0 (4)	40.0 (14)	8.0 (11)	51.5 (20)
Wind												
Mean Speed (m/s)	2.2	1.9	2.0	2.0	1.7	1.6	1.2	1.1	1.3	1.8	1.5	1.6
Maximum Speed (m/s)	7.0	6.5	6.7	6.5	7.4	5.1	4.4	4.2	6.3	5.7	5.9	5.2

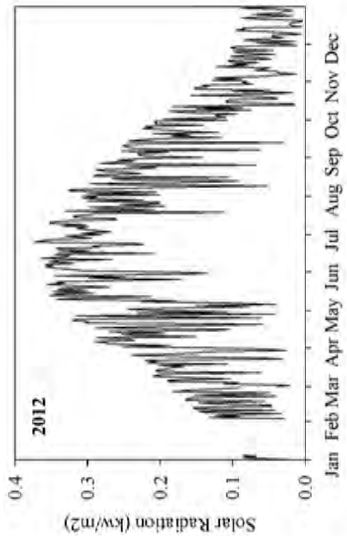
1- NA, not available. Pyranometer removed for maintenance, Jan. 6 - Feb. 2.



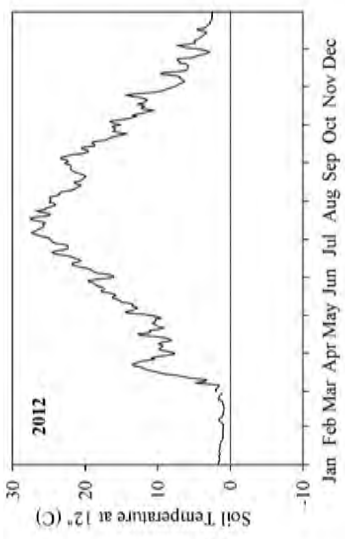
Mean Daily Temperature



Total Daily Precipitation



Mean Soil Temperature at 12" Depth



Mean Daily Radiation

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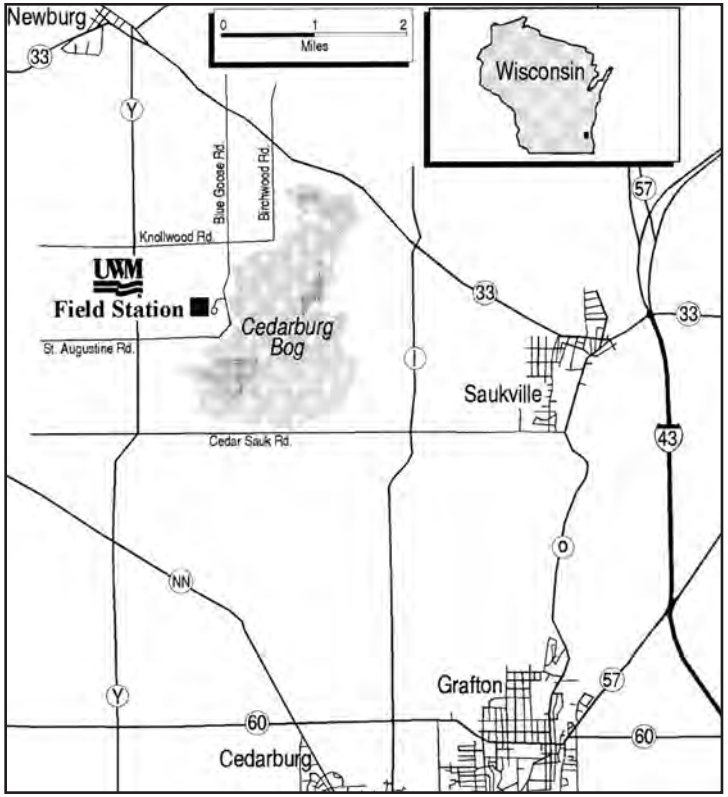

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