2015 Field Station Annual Report

UNIVERSITY of WISCONSIN
UWMILWAUKEE
Field Station

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On the Cover: The Friends of Cedarburg Bog buckthorn crew, Josh Pletzer, Jamie Beaupre (Project Manager), and Doug Stadler (L-R), taking a break from cutting and treating buckthorn in the Bog. FOCB received a large grant to remove buckthorn from the Bog (see pages 2 & 6), and the crew has cleared almost 200 acres of that invasive shrub in the first year of this two-year project. Winter is the best time to do that work in the Bog.

About Us

2015 Highlights

• We added a new mammal to our species list! Wildlife biologists suspected that we had a flying squirrel population at the Station, but over our 50 year existence the work had never been done to document their occurrence. Well, we have now added them to the list of Field Station vertebrates. See the abstract by Amanda Keyes.

• The Friends of Cedarburg Bog obtained almost $200,000 from the US EPA to control buckthorn in hundreds of acres of the Bog. This two-year project began in 2015, and FOCB has hired a crew to conduct that control work. The Field Station is helping to direct and manage the project.

• A "lowlight" for 2015: Emerald Ash Borer has become firmly established in the Field Station area and a large-scale die-off of ash trees in the forest is underway.

• Continued expansion of the on-line component of our Natural History Workshops so that more of those topics are now offered as "blended" in-person/online courses for college credit.

• 37 research projects in 2015

• Almost 14,000 person-hours of instruction and group use in 2015. Use of our Downer Woods on the main campus for instruction continues to increase now that the worst invasive plant problems are largely under control and the forest is recovering.

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 357 scientific publications and 147 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. The Bog is part of the national system of Experimental Ecological Reserves established by the National Science Foundation and The Institute of Ecology. 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. In 2015, the DNR purchased 66 acres of land in the Cedarburg Bog from The Bog Golf Course, the first major addition of acreage to the State Natural Area in decades. Emerald Ash Borer is now well-established in the Cedarburg Bog and most of the ash in the Bog are dead or dying. Approximately 12% of the trees in the Cedarburg Bog were black ash, accounting for 10% of total tree basal area, and 2% were green ash, 4% of basal area. We expect to lose all of these ash; most are already dead.

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. We have known that Emerald Ash Borer beetles have been present in the woods since 2012 when adults were captured in traps at the Station. It appears that most of the white ash in the upland forest are now dead; we expect to lose all of the ash. White ash makes up about 9% of the trees in the forest and 13% of the total basal area of trees. 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. We conducted controlled burns of three prairie/old-field areas (Burn units 1, 3, and 5) on 6 April 2015 with Field Station staff and volunteers.

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 both 2012 and 2013. 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 long-term control throughout the natural areas seems intractable with the hand and mechanical methods we are using elsewhere. Since 1991 fruiting-sized buckthorn has been cut and treated with herbicide in various selected control plots in the northern and central parts of the Bog by the Wisconsin DNR and the Friends of Cedarburg Bog. This year FOCB received a $197,000 Great Lakes Restoration Initiative grant from the US EPA, $9,300 from the Wisconsin Knowles-Nelson Stewardship Program, and $7,900 from the We Energies Foundation through the Natural Resources Foundation of Wisconsin for buckthorn control work in the Bog. With a total budget of almost $250,000 for a two-year project, FOCB has a very ambitious goal to remove fruiting-sized buckthorn from 680 acres of the Bog. This will bring the total area that has received buckthorn control since 2012 to almost 900 acres.

Research and Teaching Facilities

General Facilities

- Office/classroom building with meeting rooms, teaching lab, and computer lab
- Research Lab constructed in 2004
- Service building – machine & wood shop
- The Farm House for researcher & student housing – The kitchen was remodeled and modernized in 2013
- 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 – new piezometers added in 2013

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
- Flying squirrel 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)

Clearing rubble from a Neda Mine bat grate

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. 2015 was the first year that the fungus that causes white-nose syndrome in bats was positively detected at the Neda Mine Hibernaculum, although the disease has not yet been confirmed in the bat population. We expect white-nose syndrome to affect the bat population in the hibernaculum over the coming years. 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

Benedict Prairie burned

Station Bulletin. Woody plants were cut from the prairie and controlled burns were conducted in spring of both 2012 and 2013. More extensive woody plant brush removal was conducted in 2014, and the prairie was burned again on 15 April 2015.

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. These invasive species are far from eliminated, but they are now well in control in Downer Woods.

UWM Innovation Campus – The UWM Monarch Conservancy – In the northwest-

ern part of UWM's new Innovation 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 conservation goal for this site is 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.

Field Station Programs

• 37 active research projects conducted at the Field Station in 2015.

• Including: 4 M.S. thesis, 3 Ph.D. and 11 studies by researchers from outside of the University.

• 14 papers published during 2015. 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) & 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.

• Drs. Peter Dunn and Linda Whittingham have conducted long-term studies on tree swallows and sexual selection.

• Records of long-term (30 year) research projects conducted by Dr. Charles Weise, on Black-capped Chickadees, Dark-eyed Juncos, breeding bird surveys of the Cedarburg Bog & upland woods, and a bird-netting and banding program conducted in fall.

• The Field Station was a major site for long-term studies of avian vocalizations, including their organization and function, by Dr. Millicent Ficken.

• Herpetological research has been a major research area at the Field Station for over a decade. Knowledge of our amphibian and reptile populations has been contributed by Dr. Gerlinde Hoebel, Dr. Gary Casper, and Dr. Joshua Kapfer.

• Dr. Jeffery Karron's research on pollination mechanisms has contributed to long-term information on the pollinators of the Field Station.

• GIS developed for the Field Station area

Educational Programs

• Almost 14,000 person-hours of instruction and group use in 2015.

• Ten workshops on topics in natural history.

• Long-time volunteer naturalist at the Field Station, Kate Redmond a.k.a. The Bug Lady, writes "Bug of the Week", which are essays on local bugs. There are now over 400 of these excellent and entertaining essays posted on the Field Station website (https://www4.uwm.edu/fieldstation/naturalhistory/bugoftheweek/). Bug of the Week has become by far the most visited feature of our website.

• 3 undergraduate student projects.

• 17 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 Friends of the Cedarburg Bog (FOCB) celebrated its tenth anniversary in 2015. The FOCB Board of Directors devoted significant effort in 2015 to creating the first strategic Action Plan for the organization. This plan focuses the Friends' effort in five areas:

• Strengthen Community Support for the Bog – The Bog can be best protected through well-informed collaboration of its immediate and extended communities.

• Expand FOCB's Conservation Impact – Stewardship efforts must grow faster than the encroaching dangers to the Bog's sensi-

tive communities.

• Extend the use of the Bog as a Natural History Classroom and Laboratory.

• Be a Good Partner – Increase collaboration with like-minded organizations.

• Be a Healthy Organization – Strengthen FOCB's focus, finances and effectiveness.

Some of the main highlights and challenges for FOCB in 2015 include:

• FOCB membership grew by 10%, donations grew by 240% to over $72,000, and the permanent endowment was up over 400% from last year.

• The Bog has many long-time supporters, who may live at some distance but have a real connection to the Bog. In 2015 FOCB initiated an effort to engage and attract more of the Bog's geographic neighbors to build an invested, informed and energized Bog "neighborhood" to collectively protect this unique property.

• FOCB supported the DNR acquisition of 66 acres of the Bog from The Bog Golf Course, the first major land acquisition for the State Natural Area property in decades.

• 2015 marked the first update of the DNR's master plan for the Bog in over 30 years and the Friends played a significant role in providing input to the plan's content.

• The Friends began its most ambitious stewardship project to date when the organization was selected for a $197,000 grant from the EPA to mitigate buckthorn encroachment in the Bog. With additional grants from the Natural Resource Foundation of Wisconsin and the DNR, and considering volunteer labor, that project is valued at over a quarter of a million dollars. The magnitude of the effort is stretching the capacity and competency of FOCB in many ways—all good. Within two years, FOCB hopes to have controlled fruiting-sized buckthorn in nearly 700 acres of the Bog.

• The Friends continued their well-received educational programs, offering 17 events on wide-ranging topics – from bird box building and dragonfly explorations to owl "prowls" and Bog ecology meanderings. And FOCB published four installments of The BogHaunter newsletter.

• FOCB committed funding of $5,000 to support the Field Station's Natural History Workshops, and is now a sponsor of that program. Additionally, FOCB made a financial commitment to UW-M to support up to three student studies per year that focus on better understanding the Bog and its watershed.

• Despite the dramatic growth of the FOCB endowment, it remains too small to provide the funds necessary to support ongoing FOCB operations. This means contributions and grants remain critical in sustaining FOCB's growing financial commitments.

• FOCB's paid workforce grew during 2015 from one part-time administrative assistant to a total of four employees – with three new, full-time, limited term field workers. Competencies that many organizations might take for granted—screening, hiring, overseeing, paying and supervising these employees--day-in-and day-out have challenged FOCB's mostly volunteer organization to gain competency and capacity quickly.

The founders of the Friends should consider the progress made by this ten-year old organization with some justifiable pride. FOCB has focused their efforts on the truly important and expanded their capacity to deliver it—they are positioned to make an even greater positive impact on this special land and its community. 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, or visit the FOCB website, www.bogfriends.org.

Abstracts of Research

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 2015 we continued herptile, crayfish and bird monitoring at several OWLT properties.

Wisconsin Herp Atlas

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The Wisconsin Herp Atlas is a distribution database of amphibians and reptiles in Wisconsin. The author initiated the Atlas in 1986 at the Milwaukee Public Museum, with the cooperative support of the Natural Heritage Inventory Program (WDNR) and The Nature Conservancy (Wisconsin Chapter). 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 600 new county records have been confirmed by the project. The data collected helps to map species distributions, document rare species occurrences, analyze distribution and habitat associations, and plan conservation priorities. In 2007 the Atlas was moved to the UWM Field Station, and currently houses over 73,000 occurrence records for Wisconsin. Record collection and vetting continued in 2015, and 62 new county distribution records were published.

National Park Service Great Lakes Network Amphibian Monitoring Program

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The goal of this project is to implement amphibian monitoring in seven National Parks in the Western Great Lakes region. A protocol utilizing automated recording systems and supplemental visual surveys was completed in 2012, and we began implementing the program in three parks in 2013. In 2015 we expanded to seven Parks. Funded by the National Park Service.

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. Few data are available for evaluating the conservation effectiveness of these structures. This project will assess the effectiveness of ecopassages in Southeastern Wisconsin, and collect data on patterns of wildlife use. Funded by C.D. Besadny Conservation Grant, Natural Resources Foundation of WI, and Wisconsin Department of Transportation.

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 Ozaukee County portion of the Milwaukee River Basin, for ranking habitat restoration sites for best value. Work continued in 2015. Funded by EPA Great Lakes Restoration Initiative and Wisconsin Coastal Management Program awards to Ozaukee County.

Wildlife Population Assessment for the Milwaukee Estuary Area of Concern

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The goal of this 3-year project is to evaluate the status of selected wildlife populations in the Milwaukee County portion of the Milwaukee River Area of Concern, and make recommendations for addressing Beneficial Use Impairments through habitat restoration projects and monitoring. The project is coordinated with Milwaukee County Parks, participating under separate funding. Work includes historical data collection, wildlife surveys, landowner outreach, and reporting. Work began in 2014 and continued in 2015. Funded by the Wisconsin DNR and the U.S. Environmental Protection Agency.

Pair of Virginia rails found in Milwaukee County

Effects of *Metriocnemus knabi* Predation on Bacterivorous Ciliates in *Sarracenia purpurea* Pitchers

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Decomposition of prey in the leaves of the carnivorous pitcher plant *Sarracenia purpurea* provides energy that supports an inquiline community consisting of bacteria, protozoans, rotifers, mites, and dipteran larvae. The natural history of this community is well described, and it is historically organized into a four trophic-level food web with bacteria as the basal level supporting protozoa, the bacterivorous bdelloid rotifer *Habrotrocha rosa* and filter-feeding larvae of the pitcher plant mosquito *Wyeomyia smithii*. Rotifers and protozoa are consumed by the mosquito larvae; rotifers are

also consumed by the raptorial larvae of the flesh fly *Fletcherimyia fletcheri*. Larvae of the pitcher plant midge *Metriocnemus knabi* feed on drowned arthropods and, in a processing chain commensalism, promote bacterial growth and a subsequent increase in larval mosquito biomass. We recently reported that midge larvae also consume rotifers. In this study, we further tease apart the interactions among *W. smithii* and *M. knabi* larvae, *H. rosa* and two common bacterivorous pitcher ciliates. We reconstituted food webs in a factorial design experiment in 50 mL plastic centrifuge tubes using wood ants as "prey." The experiment ran for two weeks; ants were added on days 1 and 7.

As expected, predation by both *W. smithii* and *M. knabi* caused significant decreases in rotifer numbers and drove them to near extinction by 14 days ($p < 0.001$). *W. smithii* also caused significant reductions in *Colpoda* and *Cyclidium* ($p < 0.01$). Unexpectedly, both ciliates were reduced to very low numbers by *M. knabi* larvae ($p < .01$). In each case, there were significant additive interactions between the two predators resulting in decreases in the two ciliates after one and two weeks ($p < 0.03$ for *Colpoda*; and $p < 0.0001$ for *Cyclidium*). There was a significant interaction between midges and mosquitoes for rotifers, but only after two weeks ($p < 0.0001$). In natural pitcher communities, it is not uncommon to find rotifers and ciliates in the presence of both dipteran consumers. We hypothesize that a spatial refugium exists within the pitcher based on the feeding behavior of the two consumers. By demonstrating that midges consume both rotifers and ciliates, we now have reason to redraw the pitcher plant inquilines food web. We suggest that both *W. smithii* and *M. knabi* together form a guild of keystone predators.

Effects of Food Abundance on the Timing of Breeding in Tree Swallows

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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. In 2015 we completed the 19th year of study of the reproductive ecology of tree swallows at the UWM Field Station. One of our main goals is to determine how environmental factors, particularly temperature and food abundance, influence the timing of breeding and reproductive success. A prominent hypothesis predicts that reproductive success is maximized when animals synchronize their reproduction with seasonal peaks in food supply. This mismatch hypothesis does not seem to be supported in tree swallows, and many other species. Instead, reproductive success appears to be more closely related to the absolute levels of food, rather than to the timing of food. We thank Gretchen Meyer and Lou Nelson for their assistance, particularly in collecting data. This research was supported by funds from the College of Letters and Science, UWM.

Genetic Assessment of Management and Restoration Practices of the Federally Threatened Orchid, *Platanthera leucophaea* (Eastern Prairie Fringed Orchid)

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Over the summer of 2015 we completed range-wide genetic sampling of *Platanthera leucophaea*. Claire Ellwanger and Cathy Pollack collected leaf tissue samples from 18 populations and received leaf samples from 14 populations thanks to collaborators like Jim Reinartz (UWM Field Station) across the range of the species. At the Chicago Botanic Garden, Claire and three undergraduate interns extracted DNA from a total of 698 leaf tissue samples over the summer. During the fall and early winter of 2015 Claire and Laura Steger completed genetic methods testing for the microsatellite primers. We are proceeding to the genetic analysis of the 32 populations included in the study, which includes the samples collected from the Cedarburg Bog. Data analysis will continue in 2016.

Funded by the Great Lakes Restoration Initiative and a Botanical Society of America Graduate Research Award.

Climate Impact on Groundwater Flow Processes in the Cedar Creek Watershed and Cedarburg Bog

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A local-scale groundwater-flow model of the Cedar Creek Watershed and Cedarburg Bog area was constructed to determine the effects of future changes in temperature and precipitation on water resources. The Cedar Creek Watershed is a 330 km^2 sub-basin of the Milwaukee River Watershed located about 30 km north of Milwaukee. The importance of this watershed lies in its location at the sub-continental divide separating the Mississippi River Basin from the Great Lakes Basin. The coupled steady-state and transient flow models incorporate interaction between surface water features and groundwater-surface water interactions. The 4 layer model simulates the influence of recharge on the local flow regime using recharge estimates using the Soil-Water-Balance Code (SWB) from the USGS. The model contains two geologic units, surficial glacial deposits and the Silurian dolomitic bedrock. The hydraulic conductivities and storage parameters were calibrated using the parameter estimation software, PEST, based on 192 head targets of the static groundwater level reported by well drillers over the past four decades. Calibrated hydraulic conductivities from a 15-year average climate result in model simulations with residual mean of 0.14 m, standard deviation of 2.68 m and RMS error of 2.69 m. Results from the simulations show that the water table remains relatively stable over years of very low recharge and very high recharge, in addition to an approximate three month lag of lowering groundwater table after a summer of significant low recharge. M.S. Thesis research, Dr. Weon Shik Han, Major Advisor.

The Carnivorous Pitcher Plant *Sarracenia purpurea* Harbors a Diverse Eukaryotic and Bacterial Flora to Aid Prey Digestion

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The pitcher plant *Sarracenia purpurea* grows in nutrient-deficient wetlands such as Cedarburg Bog and supplements mineral nutrition by carnivory. Newly formed pitchers are sterile, but fill with rainwater, in which insect prey drown. Within the pitcher detrital food web, invertebrates begin macroscopic breakdown of prey while microbial hydrolytic enzymes (chitinases, phosphatases, proteases) digest and release nutrients, prior to absorption by the plant. These micro-ecosystems are the target of trophic food web studies, but more detailed functional analysis of bacteria and eukaryotic taxa are lacking. In order to characterize the pitcher community composition and function, this research addressed three specific ques-

tions: What bacteria and eukaryotic organisms are present in the pitchers? How does bacterial succession and hydrolytic enzyme activity develop in *Sarracenia purpurea* over the lifespan of a pitcher, from opening to senescence? How do possible sources of

bacteria (rain, captured prey) affect bacterial abundance and enzyme activity in the community? Pitcher plants in the Cedarburg Bog were sampled in 2013 and 2015; plants were also transplanted from the bog and monitored under greenhouse conditions to control sources of bacteria added to pitchers. Bacteria and eukaryotes were identified using analysis of 16S and 18S rRNA gene sequences, enzyme activities were measured using biochemical assays, and bacterial cell abundance estimated by epifluorescence microscopy. Pitchers harbored diverse bacteria and eukaryotic ciliates, arthropods including springtails and mites, fungi, and protists including green algae. Enzyme activity increased for 2 weeks after pitcher opening and then became variable, with a 145-fold variation in hydrolytic enzyme activity measured in 20 pitchers over the summer. Enzyme activity in field samples may vary in relation to detritus (prey) load in the pitchers, which can increase with pitcher age. In the greenhouse plants, with different bacterial sources, adding prey increased hydrolytic enzyme activity compared with distilled water controls, but there was also a 35-fold variation in hydrolytic enzyme activity measured in 35 pitchers. Pitcher plants harbor a diverse population of bacteria and eukaryotes which play roles in the detrital food web from which the plant host gains nutrients. Ph.D. research, Dr. Erica Young, Major Advisor.

Experimental Reduction in Bumble Bee Visitation Promotes Increased Wasp Visitation to Whorled Milkweed (*Asclepias verticillata*)

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Changes in the local pollinator community may shape the dynamics of plant-pollinator interactions. Since the quality of pollination services often varies markedly among pollinator species, the consequences of pollinator declines for plant reproductive success may be unpredictable. Therefore, changes in the composition of visiting pollinators, in terms of their pollination efficiency and visitation rates, may play a significant role in determining the effect of pollinator loss on plant reproductive success. If the loss of a major pollinator leads to increased visitation by another efficient pollinator, pollination success may remain unchanged or may even increase. We experimentally tested this hypothesis by removing bumble bees from plots of whorled milkweed (*Asclepias verticillata*). In three small and three large populations, we quantified pollinator visitation rates and pollination success for control plots and for plots where bumble bees were experimentally excluded. We found that exclusion of bumble bees led to a substantial increase in wasp visitation in all six populations. However, small populations experienced a less dramatic increase than did large populations. Since wasps and

bumble bees are both efficient pollinators of whorled milkweed, increased wasp visitation offset the loss of bumble bees, and pollination success remained unchanged. This provides a vivid example of the challenges associated with forecasting how pollinator declines will influence plant reproductive success. This work was supported by a UWM Research Growth Initiative Grant. MS Thesis research, Dr. Jeffrey Karron, Major Advisor.

Parasitism and Ornamentation: a Within-individual Study in the Common Yellowthroat

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Elaborate ornaments are hypothesized to honestly signal individual quality, including the ability of an individual to combat parasitic infection. Although there have been many studies of this hypothesis, the results of these studies have been mixed. One explanation for these varying results is that measures of ornaments and parasitic infection intensity are typically obtained only once for each individual. Therefore, correlations between ornamentation and parasitic infection intensity do not consider within-individual relationships, which may differ from between-individual relationships. We examined the relationship between ornaments and intensity of infection by haemosporidian parasites within individuals (using data from two breeding seasons) in the common yellowthroat, *Geothlypis trichas.* Male common yellowthroats have two ornaments, a melanin-based (black) mask and a carotenoid-based (yellow) bib, and in our study population females prefer to mate with males that have larger black masks. In addition, mask size is positively correlated with antibody production, body condition, survival, resistance to oxidative stress, and immune gene variation (major histocompatibility complex, MHC). Of the males analyzed over two years, 89.3% were infected with haemosporidian parasites during at least one breeding season. Interestingly, we found a positive within-individual relationship between mask size and infection intensity, but no relationship across individuals. This result is potentially explained by the high costs of immune response, which may outweigh the benefits of parasite clearance. Ph.D. research, Dr. Linda Whittingham, Major Advisor.

Multimodal Communication in Eastern Gray Treefrogs, *Hyla versicolor*

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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. We

also conducted playback experiments with female gray treefrogs to evaluate whether they are attracted to visual (video of calling male) signal components, and started conducting preliminary trials testing whether females respond to vibrational signal components. Funded by the Research Growth Initiative, UWM.

Audiovisual Integration and Leader Preferences

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Humans perceive several sounds in close temporal succession as a single event originating from the location of the leading sound, a trick played by the auditory system to improve sound localization. Surprisingly, a visual cue associated with the leading sound enhances sound localization, while a visual cue associated with the lagging sound inhibits it, suggesting that auditory spatial perception in humans is a fundamentally multisensory process. Many animals also focus on leading calls. For example, a female frog will approach the source of the first of two calls in close succession, resulting in higher mating success for the leading male. Whether visual cues affect the expression of leader preferences is unknown, but the fact that communication is frequently multimodal (i.e., a frog cannot produce a call without inflating his conspicuous vocal sac) suggests that this might be the case. We explored whether audiovisual integration during sound localization is unique to humans, or a general feature of animal sensory perception by conducting playback experiments with female treefrogs in which we compared their responses to sound alone, or sound combined with a visual cue (an LED). Funded by the Research Growth Initiative, UWM.

Behavioral Ecology of Color Change in Gray Treefrogs

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Gray treefrogs (*Hyla versicolor*) have amazing color change ability, and can range from dark brown to bright green. Yet, nothing is known about the distribution of body color in nature, or whether frogs choose their resting perches based on their body color, or adjust body color as a function of ambient color or temperature. Here, we examine the behavioral ecology of color change in gray treefrogs. Color change can function to hide the individual from predators (crypsis), or to make the individual obvious for conspecifics (conspicuousness). In addition, in ectotherms (cold blooded animals), body color may help with thermoregulation (darker colors heat up better, brighter colors increase reflection and stay cooler). We took pictures and temperature measurements from (i) calling males at the pond at night, and (ii) male and female frogs resting during the day. The daytime pictures were taken from frogs released in a large enclosure fitted with branches and foliage (treefrogs spend the day resting in the tree canopy, making it impossible to sample frog body color in nature). We will analyze color and contrast measures from the frogs to test whether temperature or background color is a better predictor of frog body color.

Handedness and Behavioral Lateralization in Anurans

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Surviving and reproducing successfully depend on an animal's ability to process information from the environment and respond adaptively. In many situations an individual must perform different activities at the same time (i.e. foraging and predator vigilance). If these activities compete for the same computational resource, for example, if both require visual or auditory attention, the brain's ability to process the information may constrain the performance of both tasks. Behavioral Lateralization, where different types of information are channeled into the two separate halves of the brain, thereby allowing parallel processing to take place in the two brain hemispheres, may alleviate this problem. Lateralized motor preference (i.e., preferential limb use or "handedness") may be associated with brain lateralization. For example, in humans brain lateralization for language and handedness are linked. Lateralization and handedness, once believed to be a unique feature of the human brain, is now recognized to be also present among vertebrates and even some invertebrates. Data for amphibians, however, is still very scarce. We have initiated a project examining handedness and behavioral lateralization in frogs. Preliminary data from gray treefrogs (*Hyla versicolor*) suggest that these frogs show individual handedness in some -but not all- behavioral tasks.

Factors Controlling Diffusive CO2 Transport and Production in the Cedarburg Bog, Saukville, Wisconsin

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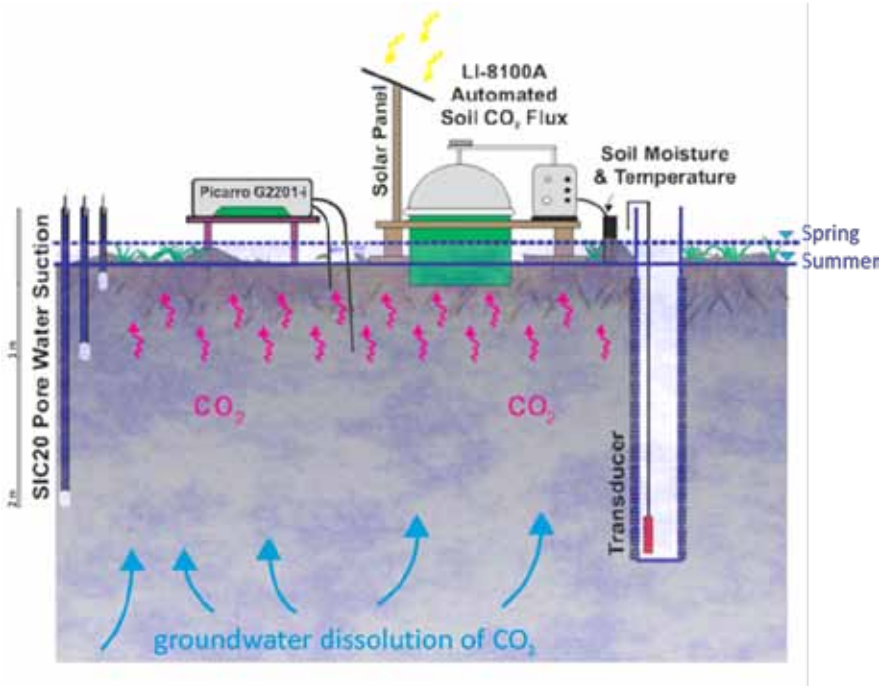
Wetlands are vital components of the carbon cycle containing an estimated 20-30% of the global soil carbon store. The Cedarburg Bog of southeastern Wisconsin boasts a myriad of wetland habitats including the southernmost string bog found in North America. Carbon dioxide (CO_2) behavior in these systems is the response of multiple interdependent variables that are, collectively, not well understood. Modeling this behavior in future climate scenarios requires detailed representation of relationships within highly diverse environments. In 2014 a LI-COR 8100A automated soil gas flux system was installed in a hollow of the Cedarburg Bog string bog, measuring diffusive CO_2 concentration and flux. Groundwater data, soil temperature, and weather data

Field instalation of the LI-COR 8100A automated soil gas flux analyzer

(temperature, pressure, etc.) were included to elucidate correlations between soil CO_2 flux/CO_2 concentration and external forces. In 2015 field data were complemented with soil moisture data and depth profile sampling of pore water chemistry and stable carbon isotopes from peat and gaseous media in order to discern the source and evolution of CO_2 at depth.

Preliminary LI-COR data analysis reveals distinct diurnal and seasonal trends; CO_2 concentration builds overnight while flux increases during the day. CO_2 flux magnitude and CO_2 concentration range peak in mid-summer, but frequency of increased CO_2 flux events is greatest in spring. Overall flux averages 7.55 $mgCO_2/min\text{-}m^2$ during the day but reaches 530 $mgCO_2/min\text{-}m^2$, and in several instances negative flux events are observed. Increased atmospheric and soil temperatures and decreasing atmospheric pressure are all observed to prelude increasing CO_2 flux intensity, though correlation significance yields a wide array of strengths. Initial gaseous $\delta^{13}C(CO_2)$ data show average $\delta^{13}C$ of ~18‰ with depleting values overnight, suggesting increasing microbial metabolic efficiency. Soil media reveal a microbial biomass $\delta^{13}C$ of roughly -21 to -22‰. Further interpretation of data trends will utilize the HYDRUS-1D model to quantify relationships under changing environmental conditions. M.S. Thesis research, Dr. Weon Shik Han, Major Advisor.



Conceptual model of field equipment and subsurface measurement, deployed along the boardwalk loop of the Cedarburg Bog string bog

Use of Mark-Recapture Techniques to Estimate Turtle Populations at the UWM Field Station

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Information on long-term trends in reptile populations can yield useful conservation information. This is particularly true because long-term monitoring projects that involve reptile populations are relatively uncommon, especially in Wisconsin. In 2006 we began an annual turtle survey on the Field Station Grounds, lasting for three days each year in late May/early June. We set turtle hoop traps approved by the Wisconsin DNR in several locations, which we checked daily during annual surveys. All of the animals captured were marked via marginal scute notches, following a well-established system. To-date, we have captured a total of 95 painted turtles (*Chrysemys picta*; mean=11.9/year), of which 13 were recaptures (1.6/year). We also captured 13 snapping turtles (*Chelydra serpentina*; mean= 1.6/year), with zero recaptures. During this time we captured only one other species, a single adult Blanding's turtle (*Emydoidea blandingii*). Data collection will continue and future analyses will be conducted to elucidate information on abundance and survival rates. Collection of this type of long-term baseline data is critical to understand population fluctuations that may occur over time and the associated conservation implications.

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 (e.g., Un-baised Lincoln-Petersen estimator). Surveys consisted of four periods, each lasting ca. 2 h, 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, annual captures of novel individuals ranged from five to nine (annual recaptures ranged 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.

Survey for Flying Squirrels at the UWM Field Station

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Conservation of biodiversity requires accurate species lists for particular properties and monitoring of population trends over time, to detect population declines for species of interest before they become severe. The UWM Field Station property includes a high-quality old-growth beech-maple forest that is one of the best remaining examples of this type of forest in southeastern Wisconsin. The Field Station maintains a list of the mammals that can be found in the forest, but the southern flying squirrel (*Glaucomys volans*) has never been documented there. Flying squirrels are not frequently seen because they nest in cavities and are active only at night, so it was entirely possible that flying squirrels were inhabiting the forest but that they had not been detected. For this project, ten nest boxes were secured to trees along a transect in the old-growth beech-maple forest. The boxes were checked once a month for nesting material, nuts, or *G. volans*. A second method used for detection was a feeding tray. A wildlife camera was trained on the feeding tray, capturing images of nocturnal visitors. In 2015, the wildlife camera documented *G. volans* at the feeding trays. No signs of flying squirrels were found in the nest boxes. Results from the wildlife camera, plus data on *G. volans* from other sites in the Milwaukee area, are currently being analyzed. Undergraduate research project, Dr. Gretchen Meyer, advisor.

Flying squirrel in a feeding tray photographed during the night by a wildlife camera

Long-term Dynamics of Southeastern Wisconsin Prairie Remnants

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Across the Midwest, less than one percent of pre-settlement prairies exist today – having been largely converted to agriculture via Euro-American settlement. These remnant communities often manifest in tiny, widely scattered and marginal populations of questionable viability. Understanding how the remaining remnants respond to both historical and changing environmental conditions is critical to managing their continued presence on the landscape. We are revisiting 62 prairie remnants in southeastern Wisconsin that were originally surveyed in the 1950s by Philip Whitford, working out of UW-Milwaukee. At each site in the original survey, a list of all vascular species was made, based on observations made at multiple visits during the growing season. At approximately half of the sites, quantitative measures of abundance were also estimated, using 20, 1/4m^2 quadrats, spaced evenly throughout the site. With these data, we ask how prairie remnants have changed over the past 60 years and how these changes correlate with land-use history and local environmental conditions.

As expected, remnants prairies have changed considerably over the past 60 years, with a range of 15-70% species loss at individual sites. Species loss was non-random and was concentrated in species with low height, small seeds and lacking vegetative reproduction. Woody plant density increased dramatically between the 1950s and today, with some sites being totally lost to forest conversion with only an occasional prairie species surviving in edge or gap microhabitats. At the site level, management by fire was the most important variable, with fire-managed sites losing fewer of the original species and generally maintaining a higher floristic quality. In general, prairie remnants along railroad corridors persisted better than did remnants in other settings, particularly those wet prairie remnants that survived into the 1950s along field edges. Apparently, extensive "improvements" (drainage tile, ditches) have effectively eliminated these remnants from the current agricultural landscape, further reducing the total remnant area in SE Wisconsin and reducing the probability of metapopulation persistence, even in higher quality remnants. The UWM Field Station's Benedict Prairie, Kenosha County, is one of our study areas.

Survey of Hymenoptera Pollinator Populations on Washington Island, Wisconsin

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Pollinating insects are highly beneficial in both natural ecosystems and agriculture, but many species are in decline. This project's goal was to survey Hymenoptera pollinators on Washington Island, WI, and to explore factors influencing their abundance and diversity. The two sites included the Washington Island Butterfly House, which has undergone extensive prairie restoration, and Sweet Mountain Farm, an apiary breeding western honey bees. Surveys took place 1-3 times per week, during which records on flowering species, weather conditions, and pollinators were obtained. Each day, three patches of flowering plants were chosen to include the most prevalent species within

a one m^2 quadrat and observed for ten minutes after a one minute "resting period". All insects that contacted a flower were tallied as pollinators. At both sites, varying numbers of honey bees, bumblebees, sweat bees, and wasps were found visiting flowers.

Results showed that along with a higher plant diversity, the Butterfly House had greater variety and abundance of Hymenoptera, with 53% sweat bees, 19% honey bees, and 19% wasps. Sweet Mountain Farm, showing less plant diversity and a strong presence of invasive plants, had less variety of Hymenoptera. The site was dominated by honey bees raised on the property, which comprised nearly 75% of all pollinators recorded. At both sites, bumblebees were the least abundant species at 3-4%. In the future, the Butterfly House's prairie restoration efforts can serve as an example for other sites, like Sweet Mountain Farm, to increase both native and introduced pollinators. Undergraduate research project, Dr. Gretchen Meyer, advisor.

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 (*Perimyotis 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 bats entering and leaving the mine on a 5-minute interval 365 days per year. We have been collecting temperature data since 1996 using battery-powered temperature dataloggers at 10 locations within the

Looking down the 30 ft. deep air shaft into Neda Mine

mine and 2 locations 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. The fungus that causes White-nose syndrome, a devastating disease that attacks hibernating bats, was detected at Neda Mine in 2015. Our study provides important baseline data on hibernation behavior of healthy bats, and will help us document changes in bat behavior now that the disease has arrived at Neda Mine.

Breeding Bird Survey at the Cedarburg Bog

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The Wisconsin Breeding Bird Atlas II is the second comprehensive field study to document the distribution and abundance of bird species across Wisconsin. The first Wisconsin Breeding Bird Atlas was conducted from 1995 through 2001. The second Atlas (WBBA II) will collect data from 2015 through 2019. Field work for the atlas is conducted in geographic "blocks" based on USGS quads across all of Wisconsin. The Cedarburg Bog and the Upland Woods are located in what is termed a "specialty block." Given that the Cedarburg Bog has been designated as an "Important Bird Area" within Wisconsin, the information collected on the breeding status of birds in the Bog has special conservation significance. The information collected on breeding birds in this second atlas census will be compared to the information collected 20 years ago in the first Wisconsin Breeding Bird Atlas for purposes of providing a benchmark to evaluate bird conservation over the past 20 years within the Cedarburg Bog complex as well as within Wisconsin as a whole.

In 2015, we independently conducted atlas surveys in a wide array of habitats, e.g., upland woods, hardwood and conifer swamp, Mud and Watts Lakes, shrub-carr wetland, sedge meadow, marshes, string bog, and various types of open field environments. Whenever a bird of a particular species gave evidence of courtship or breeding or nesting, one of the following breeding designations was assigned to the species: "possible", "probable," or "confirmed." The census is off to a good start in 2015 with 66 species having been identified as possible, probable or confirmed breeders within the Bog complex. Most importantly, 40 species were confirmed as breeding this first year of WBBA II as contrasted with a total of 52 breeding species throughout the entire five years of the original WBBA from nearly 20

Pine warbler. Photo: Joel Trick

years ago. Species newly confirmed from our 2015 survey as breeders within the Bog are hooded merganser, pine warbler, chestnut-sided warbler, and winter wren. The Cedarburg Bog breeding bird atlas survey will cover many of the same areas canvassed in 2015; however, in 2016 special focus will also be given to accessing some of the more remote, less accessible areas of the inner core string bog.

Wood Duck Nest Box and Small Owl Nest/Roosting Box Project

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Beginning in 2012 and through 2015, following traditionally proven protocols for nest box construction, placement, maintenance, and monitoring, the Friends of the Cedarburg Bog (FOCB) installed 14 duck nest boxes in and around the Bog com-

plex. Eleven of the duck nest boxes were installed over land on trees near woodland ponds, lakes, or streams. In 2015 three of the boxes were installed on galvanized steel poles over water -- two in a seasonal woodland pond and one on the edge of a small cattail marsh extending 40 feet out from the shoreline of the largest island in Mud Lake. All of the boxes are equipped with steel predator guards. Over this four year period, wood duck nest box success rates increased from 25% in 2012 to an estimated 50% or better in 2015. Furthermore, for the first time ever, hooded mergansers were recording as breeding in the Cedarburg Bog when eight ducklings made their "jump" from the Mud Lake box on May 16, 2015.

The FOCB nest box program is intended to become a "citizen science" project with the goal of having more community involvement with nest box installation, monitoring, and maintenance. A small cadre of volunteers has already begun to participate in the program. In early 2015, three of the new duck nest boxes were installed with permission on private land adjacent to the Field Station. All three boxes had successful hatches, and in 2016 three additional boxes will also be installed in Mud Lake.

Four small owl boxes erected in 2012 provided minimal evidence of use in 2014, with only one box of the four being occupied by a small owl (likely an eastern

Wood ducks on Nest Box

screech owl) and this for roosting for a short period of time based on the small number of owl pellets and bird feathers found within the box. To date, there has been no evidence of any the owl boxes being used for nesting by small owls. Data for small owl nest boxes for 2015 has yet to be obtained.

Comparison of Population Growth Rates with Anhydrobiotic Survival Rates Across Multiple Temporal and Spatial Scales in a *Habrotrocha rosa* Metapopulation

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Anhydrobiosis, the phenomenon in which organisms undergo complete desiccation then rehydration, has been thoroughly studied in tardigrades and to a lesser extent in some rotifer species. We examined the bdelloid rotifer *Habrotrocha rosa* which thrives within the rainwater filled pitcher-shaped leaves of *Sarracenia purpurea*. This carnivorous plant ranges widely throughout North America and, in some areas, experiences midsummer drought-like conditions. During these periods, pitchers often remain empty for a week or more after opening. We were interested in examining recovery from desiccation in two rotifer life history types (fast vs. slow population growth rates) within a bog in southeastern Wisconsin. In addition, we examined the metabolic enzyme Phosphoglucose Isomerase (PGI). We hypothesized that variation in both *H. rosa* life history and anhydrobiotic survival is correlated with PGI isozyme. Our sampling scheme was designed to provide samples across time as well as multiple spatial scales throughout the bog. Three rotifers were randomly selected from each pitcher sampled, and each became the foundress of a clone representing one *H. rosa* genotype that was present in the pitcher on the date of collection. We examined PGI isozymes by cellulose acetate gel electrophoresis and evaluated anhydrobiotic survival by rehydrating clones four days after complete desiccation.

We found a statistically significant difference between life history types (fast and slow growing) in terms of anhydrobiotic survival ($t = 19.617$, $p < 0.0001$). Slow growing clones had fewer survivors after desiccation and rehydration (mean = 8.51 ± 0.460 survivors), while fast growing clones had more survivors (mean = 19.49 ± 0.481 survivors). We initially believed that this could be due to variations in PGI, which plays a key role in glucose metabolism and the resupply of ATP and could thereby influence reproductive rates. Furthermore, because mitochondrial energy production has been cited as essential for anhydrobiotic survival, variation in PGI could influence the ability to survive in waterless pitcher habitats during mid-summer dry spells. However, all of the *H. rosa* clones exhibited identical heterozygous genotypes for PGI regardless of growth rate. There was slight variation in the intensity of the protein bands which we believe to be the result of differences in sample density. We suggest that faster growing clones have higher metabolic rates and produce more of the bioprotectants that offset damages associated with complete desiccation. These clones may also be more successful at undergoing the anatomical changes associated with formation of the dehydrated tun.

Urban Pollination Study of Green Roofs on the UWM Campus

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Can green roofs help pollinators thrive alongside urbanization? While our cities continue to grow and green space becomes sparse, it is imperative that we supply pollinators with a resource-rich natural habitat. By analyzing pollinator use, insect diversity, floral abundance, and floral diversity, we sought to discover if green roofs can provide crucial habitat for pollinating insects. In the first year of a long-term study, we monitored

pollinator visitation at two different green roofs on the UWM campus, in comparison to a ground-level prairie planting, while developing a protocol for further monitoring.

Observations were made each week, including the identification and counting of all insects that came in contact with flowers inside of a 0.25 m^2 quadrat, identification of all plant species in bloom at each of the three observation sites, and abundance rank of all blooming species. In addition, a flower count within each quadrat was made during each observation day. Contrary to our expectations, we found that all three sites were similar in visitation rates, with a drop-off in visitation on the green roofs near the end of the season. We also found that the ground-level prairie planting had the lowest amount of variability between observations but had fewer overall visits compared to the standard *Sedum*-rich green roof. Our results show that green roofs do play a critical role in providing pollinator habitat and are therefore important in an urban environment. However, the drop-off of visitation to the

green roofs shows supplemental plantings are also vital, as the green roofs we studied only provided a short blooming period for local pollinator communities. Undergraduate research project, Dr. Gretchen Meyer and Dr. Mai Phillips, advisors.

Warming Winters and the Regional Implications for the Subnivean Climate

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Many plants and animals use the stable environment underneath the snowpack, called the subnivium, as a refuge from harsh winter weather. The depth, density, and duration of the snowpack determine the climatic conditions of the subnivium, which are typically much milder due to the insulation provided by the snow. As climate change produces warmer mean temperatures, however, the subnivium becomes colder and more thermally variable. These changing conditions can have significant effects on the physiology, survival, and distribution of species that are dependent on this habitat.

Using micro-greenhouses that are automated to maintain set temperature gradients and allow winter precipitation to fall inside,

we will assess how changing snow conditions affect the temperature and stability of the subnivium microclimate. In the fall of 2015, we deployed 27 greenhouses to nine sites representing conifer forests, deciduous forests, and open prairies. At the UWM Field Station, we have set up three micro-greenhouses in a conifer stand. While we are still in the early stages of our research, we have begun to collect data on the climate conditions within and outside each greenhouse and will be continuing this research through the winter of 2017. Funded by the National Science Foundation.

Social and Ecological Causes of Variation in Mating Signals and Mate Preferences

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We are testing the hypothesis that social and ecological environments influence the expression of mating signals and mate preferences. Using members of the *Enchenopa binotata* treehopper species complex (Hemiptera: Membracidae), we are testing the interaction between social and host plant environments. We are examining how

social groupings and host plants influence variation in male signals and female mate preferences, which have played an important role in speciation in these treehoppers. We are using a sample of treehopper full-sib families to estimate direct genetic variation, and we are using a sample of host plant clones to estimate indirect genetic variation. This captures the interaction between direct and indirect genetic components of variation. These patterns can then be compared with the magnitude of variation in signals and mate preferences among species in the complex. Our results point to considerable variation due to social and biotic environments, with interesting consequences for how speciation may begin. Funded by the National Science Foundation.

PhenoCam Monitoring of Seasonal Plant Development and Senescence At Downer Woods and the UWM Field Station

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An exciting new development in phenological science is the use of fixed cameras to provide continuous near-surface remote sensing observations of seasonal development and senescence within small patches of vegetation. The PhenoCam Network is a global project (P.I. Andrew Richardson, Harvard University, sites primarily in North America) that is designed to coordinate this type of data collection. The PhenoCam website is: http://phenocam.sr.unh.edu/webcam/

UW-Milwaukee added two nodes to the PhenoCam network with cameras installed in March 2013 on the Sandburg East Tower (viewing north toward Downer Woods, see http://phenocam.sr.unh.edu/webcam/sites/downerwoods/) and at the UW-Milwaukee Field Station (viewing a small grove of trees north of the main buildings, http://phenocam.sr.unh.edu/webcam/sites/uwmfieldsta/). The cameras record an image once every half-hour during daylight hours in both the visible and near-infrared. These data will be added to the traditional ground-based visual phenology observations and climate data collected at both sites to continue efforts to better understand phenological changes, as well as bridge the spatial and methodological gaps between visual phenology and remote sensing-derived measurements.

Natural Selection by Insect Pollinators and Seed Predators on Floral Head Traits of *Helianthus grosseserratus* (Sawtooth Sunflower)

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Flowering plants must invest energy and resources to produce floral displays that are attractive to pollinators, but these same displays may also attract detrimental insects. How floral traits are shaped by the preferences of both pollinators and herbivores/seed predators is not fully understood. Using *Helianthus grosseserratus* (sawtooth sunflower) as my study species, I investigated these conflicting selective pressures on floral head traits through a 2-year study in a large, unbroken tract of mesic prairie

in Wisconsin. In the first season, I followed individual heads over time and recorded insect visitation patterns and phenological changes to floral head traits. I also dissected seed heads at the end of the flowering period and identified all seed predators to order. In the second year, I measured floral head traits (including disc area, ray area, and UV reflectance patterns) on the day when most florets were presenting pollen. I also performed a hand-pollination experi-

ment to determine if the plants were pollen-limited or resource-limited. I recorded the number and percent developed seeds per head as measures of reproductive success and also counted and identified the seed predators in each head. I also measured the number of flowers surrounding the study head as an additional factor that may affect pollinator and herbivore/seed predator preference. Floral heads were visited by a diverse group of insects: 16 species from 7 orders were recorded. Hymenoptera, Coleoptera, and Diptera were the most common visitors. These 3 orders had highest visitation on the second or third day of pollen presentation. Seed head dissection revealed 6 orders of insect, with Thysanoptera and Diptera being the most common. In year 2, I found that pollinators were required for seed set in this system, as heads that were bagged produced negligible seed. Heads in the hand-pollination treatment had fewer developed seeds and a lower percentage of developed seeds than heads that were open-pollinated, although these differences were not significant. These results suggest that the plants were more likely to be resource-limited than pollen-limited. However, hand-pollinated heads did have significantly more seed predators than open-pollinated heads, which likely reduced seed set. Disc area was the most important trait affecting both the number of developed seeds and the number of seed predators, with larger discs having both greater seed production and more seed predators. Disc area did not influence the percentage of developed seeds, suggesting that the effects on seed number reflect the fact that a larger head has more ovules rather than pollinator attraction. The UV patterning on study heads showed significant polymorphism, where some plants had a strong bulls-eye pattern on rays, while others had no clear demarcation (50% of heads in 2013 had no demarcation; 44% in 2014). My results showed there was no relationship between this patterning and number or percentage of developed seeds, but plants with a stronger bulls-eye pattern (likely because of a reduced amount of UV-absorbing defensive pigments) had more seed predators. These results suggest that UV patterning was important for defense against seed predators. In addition, floral heads with a large ray area had fewer seed insects, while those with a short head height and a large number of flowers in surrounding area had higher number and percentage of developed seeds. Such results highlight the complexities involved in the generalist pollination syndrome and the need to consider a multitude of floral head traits when analyzing plant/insect interactions. M.S. Thesis research, Dr. Gretchen Meyer, Major Advisor.

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.

In 2015, Cooper's hawks at 18 of 32 sites that I monitored laid eggs. Fifteen of these 18 laying pairs produced 54 young to a bandable age (ca. 18 days; 3.00 young/laying pair, 3.60 young/successful pair, 83.3% nesting success). All nestlings (32 males, 22 females) were banded. Fourteen additional occupied sites were monitored but no nesting attempts were found. Eighteen adult (i.e., breeding) Cooper's hawks (9 males, 9 females) were trapped, banded, measured, colormarked, and processed for additional analyses at 11 different nest sites. All nine males were in adult plumage; seven of the nine females were in adult plumage, and two were in juvenile plumage. Two of the adult males were natal dispersals, and one of the adult females was a natal dispersal. The adult males dispersed 7.34 and 9.48 km from their natal sites, and the female dispersed 12.03 km from her natal site. No nesting attempt was found in Downer woods for either great horned owls or Cooper's hawks. One juvenile Cooper's hawk was observed in Downer Woods on 3 May 2015.

Differential Contributions of Multiple Bumble Bee Species on Reproductive Success and Mating Patterns in *Mimulus ringens*

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Over the last decade there have been startling changes in the relative abundance and diversity of bumble bee populations, including significant decline of many species both in North America and Europe. Several species often coexist within a population and it is not known whether these species provide equivalent pollination services for native flowering plants. To address this question we quantified seed set of *Mimulus ringens* flowers following individual visits by *Bombus fervidus, Bombus impatiens,* and *Bombus vagans*. These three species coexist in native populations and vary considerably in both body size and foraging behavior. In 2012, mean seed number per fruit following single visits by *Bombus vagans* (X=3131) was significantly higher than mean seed number resulting from visits by *B. impatiens* (X=2423). In 2013, mean seed number per fruit was significantly different following visits by all three species. Species comparisons of self-pollination rate and mate diversity are currently being analyzed. These results suggest that different bumble bee species may have unequal contribu-

tions to native plant reproduction. Therefore local plant reproduction may be affected by changes in pollinator composition as well as by changes in pollinator abundance. In order to address how fluctuations in pollinator composition may affect local plant populations, current research is investigating how the exclusion of different bumble bee species influence local plant reproductive success. Ph.D. dissertation research, Dr. Jeffrey Karron, Major Advisor.

Bat Activity Surveillance Monitoring at Neda Mine Hibernaculum

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White-Nose Syndrome (WNS) has spread across 26 states and 5 Canadian provinces. The fungus *Psuedogymnoascus destructans* (Pd) that causes the syndrome has been found in four other states (MN, MS, NE and OK). This deadly disease has and continues to cause massive bat mortality in eastern North America. Since the winter of 2006–2007, bat population declines ranging from 80–97% have been documented at surveyed hibernacula. Although exact numbers are difficult to determine, biologists estimate that losses may approach 5.7 to 6.7 million bats since 2007. This mortality represents the most precipitous decline of North American wildlife caused by infectious disease in recorded history.

Regrettably white-nose syndrome was confirmed in Wisconsin on March 28th, 2014. As of May 14, 2015, 14 sites in eight counties have been confirmed with either the disease-causing fungus or white-nose syndrome. Bats at sites in Grant, Crawford, Richland, Door and Dane county have tested positive for white-nose syndrome, while the fungus known to cause the disease has been confirmed at sites in Iowa, Dodge and Lafayette counties. Monitoring bat populations is crucial in states like Wisconsin that are currently considered unaffected, both for early identification of the disease and to develop pre-WNS baselines in this region.

The bat populations of Neda Mine have been inspected for WNS annually for the past five hibernation seasons and continue to be inspected at least annually. Unfortunately, on 4/29/15 bat swab samples that were collected for Pd surveillance from spring emergence trapping at Neda Mine were positive for Pd. No visible fungus or evidence of wing damage were observed on the bats sampled.

We have installed a thermal infrared surveillance system at Neda Mine. Thermal infrared surveillance is an effective tool because it can detect the change in a bat's body temperature as it arouses out of torpor, and because WNS-infected bats arouse more frequently than healthy bats. Baseline information on Neda Mine's bats will allow the infrared surveillance effort to detect WNS almost immediately if/when the disease arrives in the site. We plan to place four self-powered ultrasound detectors at four entrances to Neda mine. The weatherproof detector will record all winter and we will retrieve the unit in late May after bats have emerged in the spring. The detectors turn on every five minutes and record for 90 seconds. When recording, the echolocation calls of any bat flying near the detector will be recorded and saved. The saved calls can help establish timelines of emergence in spring and whether bats are flying in midwinter. Monitoring bat entrance activity will help us better understand spring emergence behavior prior to and post-WNS infection. Investigating temporal and environmental impacts on bat spring emergence can help better understand timing of management for bats across the state.

We also conduct fall and spring trapping of bats with harp traps and mist netting at the Neda Mine entrances. This allows us to gather important data on bats, including baseline weight and WNS wing scoring before and after hibernation as well as collecting tissue for genetic work. When a bat is in the hand of an observer it can be examined for signs of WNS and samples for diagnostics are then easy to acquire. The focal species are *Myotis lucifugus, Myotis septentrionalis; Eptesicus fuscus*; and *Perimyotis subflavus.*

Experimental Evidence that Brighter Males Sire More Extra-pair Young in Swallows

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Across taxa, extra-pair mating is widespread among socially monogamous species, but few studies have identified male ornamental traits associated with extra-pair mating success, and even fewer studies have experimentally manipulated male traits to determine if they are related directly to paternity. As a consequence, there is little evidence to support the widespread hypothesis that females choose more ornamented males as extra-pair mates. Here, we conducted an experimental study of the relationship between male plumage color and fertilization success in tree swallows (*Tachycineta bicolor*), which have one of the highest levels of extra-pair mating in birds. In this study we experimentally dulled the bright blue plumage on the back of males (with non-toxic ink markers) early in the breeding season prior to most mating. Compared with control males, dulled males sired fewer extra-pair young, and, as a result, fewer young overall. Among untreated males, brighter blue males also sired more extra-pair young, and in paired comparisons, extra-pair sires had brighter blue plumage than the within-pair male they cuckolded. These results, together with previous work on tree swallows, suggest that extra-pair mating behavior is driven by benefits to both males and females. This research was supported by funds from the College of Letters and Science, UWM.

Isolation of Novel Microbes from Natural Environments

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About 95-99% of the microbes cannot be isolated with conventional methods. In this study, we used culture-independent methods to isolate and identify microbes in natural environments. We collected soil samples from different locations at the Field Station. The r-DNA of the microbes were sequenced to study bacterial phylogeny and taxonomy. The potential natural compounds produced from the isolated microorganisms were evaluated. The properties of the compounds were examined by High Performance Liquid Chromatography and Mass spectrometry. Funded by the National Science Foundation and T3 Bioscience.

Recent Publications and Theses

Recent Publications Resulting from Field Station Projects

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Hileman, Eric T. 2010. Abundance and survivorship of Butler's gartersnake (*Thamnophis butleri*) in Wisconsin. M.S. Thesis.

Ambardar, Medhavi. 2011. Effects of habitat and predation on reproductive success in eastern bluebirds (*Sialia sialis)*. M.S.Thesis

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Graham, Jackson. 2015. Climate impact on groundwater flow processes in the Cedar Creek Watershed and Cedarburg Bog. M.S. Thesis.

Checking a Flying Squirrel nest box

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

6. Regional School Systems. Biology classes and clubs from several high schools in the region (Milwaukee, Ozaukee, and Washington counties) use the Field Station for ecology field classes.

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

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

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

10. Urban Ecology Center—Milwaukee. G. Meyer serves on the Citizen Science Advisory Council.

11. Wisconsin Invasive Species Council. Reinartz serves on the Council and chairs the Science and Research Subcommittee.

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

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

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

15. Ozaukee County. Reinartz provided assistance with planning for restoring a closed county gravel pit.

2015 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 2015.

Workshop	Instructor	Date
Ecology and Physiology of Plants in Winter: Surviving the Big Chill	James Reinartz	January 9 & 10
Creative Writing About the Natural World	Mary Linton	April 17 & 18
Wildlife Inventory and Monitoring	Gary Casper	May 29 & 30
Vegetation of Wisconsin	James Reinartz	June 15- 20
Sedges: Identification and Ecology	Anton Reznicek	June 19 & 20
Aquatic Invertebrates	Gretchen Meyer and Robert Clare	July 17 & 18
Ecological Geology	Roger Kuhns	July 27 - 31
Grasses: Identification and Ecology	Robert Freckmann	August 7 & 8
Invasive Plant Management Techniques	James Reinartz	September 19
Wetland Restoration	Alice Thompson	September 25 & 26

Sedge workshop group in June

Class and Group Use

Winter - Spring 2015

Number of Student Hours

Ecology and Physiology of Plants in Winter Workshop	360
Wildlife Inventory and Monitoring Workshop	380
Creative Writing about the Natural World Workshop	360
Winter Ecology Hike and Friends Chili Dinner	320
Friends of Cedarburg Bog – Building for Wildlife workshop	40
Friends of Cedarburg Bog – Owl-prowl Hike	60
Friends of Cedarburg Bog – Woodcocks and Frogs	70
Friends of Cedarburg Bog – Frogs & Amphibians	50
Friends of Cedarburg Bog – Bird Walk	70
Friends of Cedarburg Bog – Marsh Marigold Hike	50
Friends of Cedarburg Bog – Ecology of the Bog – North End	60
Friends of Cedarburg Bog – Spring Bird Walk	40
Friends of Cedarburg Bog – Meetings	140
Field Station Garlic Mustard Search/Pull	50
UWM Development Team – Meeting and Tour	80
River Alliance of Wisconsin – Project RED Workshop	30
Ozaukee County Quarry Committee – Working group	30
AmeriCorps – Bog Walk	70
Glendale Women's Club – Bog Walk	70
Natural Resources Foundation – Woodcocks & Frogs Hike	40
Shorewood High School – Watershed Wisdom Class	190
Wisconsin Phenology Society – Phenology program tour	50
UWM – BioSci 310 – General Ecology (Downer Woods)	1,500
UWM – Geography 120 – Our Physical Environment	290
UWM – Geophysics – Neda Mine exploration	120
TOTAL	**4,520**

Summer 2015

Vegetation of Wisconsin Workshop	1,240
Aquatic Invertebrates Workshop	320
Ecological Geology Workshop	710
Sedges: Identification and Ecology Workshop	380
Grasses: Identification and Ecology Workshop	380
Friends of Cedarburg Bog – A Walk in the Bog	80
Friends of Cedarburg Bog – Summer Solstice Hike	50
Friends of Cedarburg Bog – Dragonflies & Butterflies	70
Friends of Cedarburg Bog – Photography on the Prairie	10
Friends of Cedarburg Bog – meetings	80
UWM Retirees Association – Tour	120
River Alliance of Wisconsin – Project RED workshop	90
Town of Saukville Quarry Committee meeting	20
Dodge County Master Gardeners – Bog Tour	50
Natural Resources Foundation – Bats of Neda Mine Tours	200
UWM – Neda Mine Field Trip	30

Summer 2015

	Number of Student Hours
UWM Continuing Education – Wetland Hydrology Course	130
UWM – Sustainable Peacebuilding Retreat	120
TOTAL	**4,080**

Fall Winter 2015

Invasive Plant Management Techniques Workshop	170
Wetland Restoration Workshop	380
Friends of Cedarburg Bog / UWM BioSci – Annual Picnic	160
Friends of Cedarburg Bog – Forest Ecology Walk	50
Friends of Cedarburg Bog – How do Trees Grow?	70
Friends of Cedarburg Bog – Owl Prowl.	70
Friends of Cedarburg Bog – Ferns of the Area	50
Friends of Cedarburg Bog – meetings	80
Wisconsin DNR – Mud Lake Stakeholders Group Meeting	20
Newburg St. John Lutheran School – Bog Tour	50
Cedarburg High School – Ecology Class	440
Schlitz Audubon Center – Master Naturalist Training Class	180
Urban Ecology Center – Educators Field Trip	40
Riveredge Nature Center – Christmas Bird Count	60
Fox Valley Wild Ones – Bog Tour	80
Alverno College – Ecology Class	80
Milwaukee Institute of Art and Design – Ecology class	70
University of Illinois-Chicago– Ecology Field Trip	640
UW – Whitewater – Ecology Class	60
UWM – Office of Research – Meeting & Tour	80
UWM – Geology Club – Neda Mine	60
UWM – BioSci 310 – General Ecology (Downer Woods)	1,500
UWM – Geography – Soils	180
UWM – Geography 120 – Our Physical Environment	280
UWM – Geography 475 – Geography of Soil (Downer Woods)	110
UWM – Geography 340 – Biogeography (Downer Woods)	110
UWM – Geology – Hydrogeology	280
TOTAL	**5,350**

TOTAL 2015 Class & Group Use Hours **13,950**

Meteorological Data for 2015

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/m²)

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.

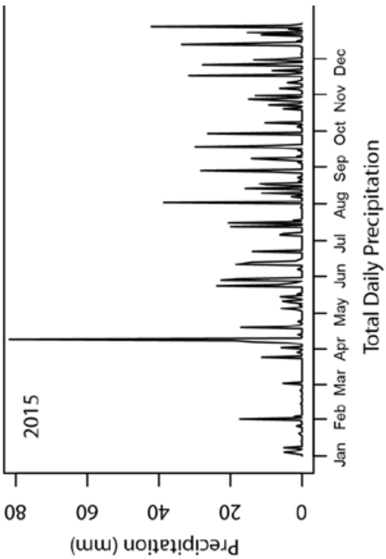
Greatest (24 hrs) (Date): Total precipitation on the day with the most precipitation and the date on which it occurred.

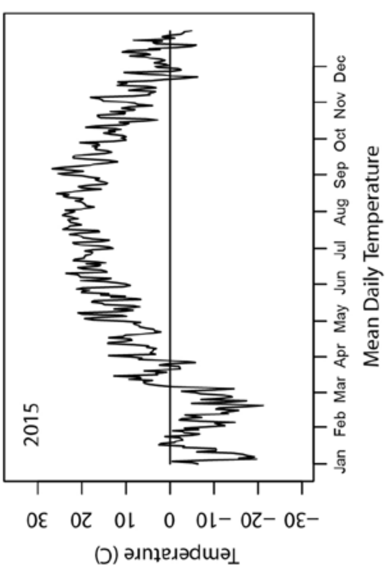
Wind

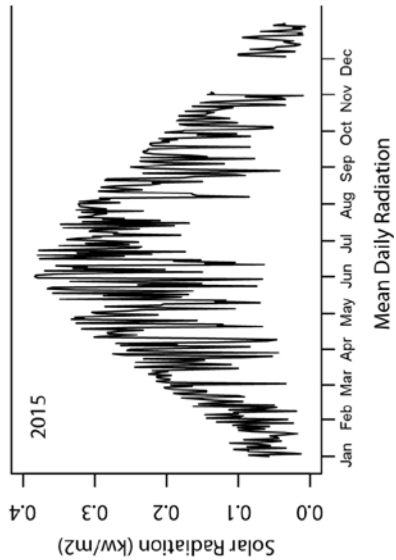
Mean Speed (m/s): Monthly mean of all 30-min means.

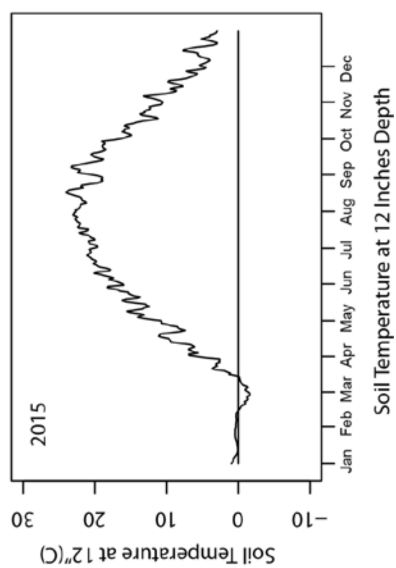
Maximum Speed (m/s): Highest mean wind speed during a 30-min period.

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.


2015
Precipitation (mm)
Total Daily Precipitation
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


2015
Temperature (C)
Mean Daily Temperature
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


2015
Solar Radiation (kw/m2)
Mean Daily Radiation
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


2015
Soil Temperature at 12"(C)
Soil Temperature at 12 Inches Depth
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

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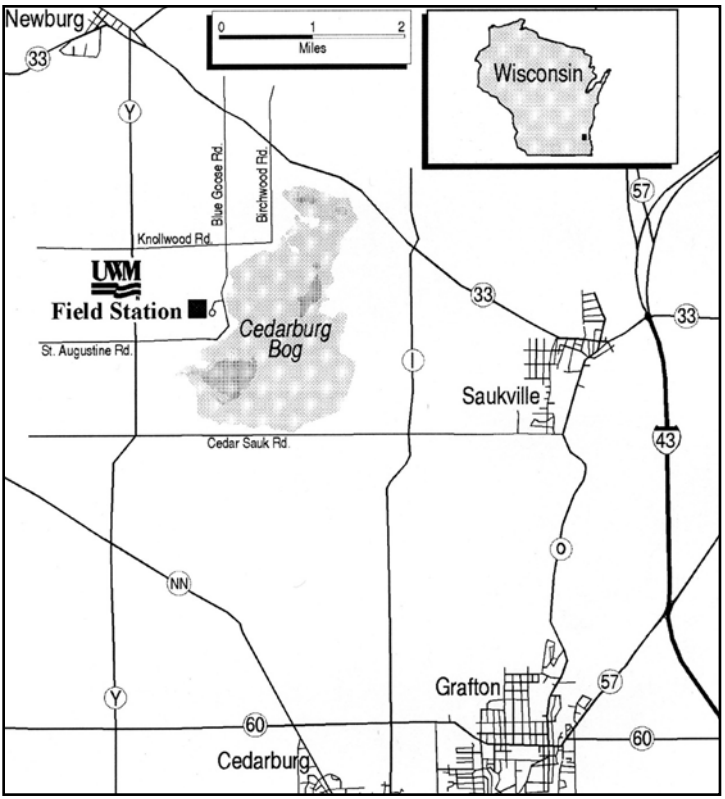

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