# 2019 Field Station Annual Report

UNIVERSITY of WISCONSIN
UWMILWAUKEE
Field Station

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***On the Cover:*** Peter Dunn and Linda Whittingham have been studying tree swallows at the Field Station for over 20 years. They were awarded the prestigous Elliott Coues award from the American Ornithological Society for their outstanding and innovative contributions to ornithological research. Tree swallow photo by Peter Dunn.

A digital version of the Annual Report with color photos can be found at the UWM Field Station website: https://uwm.edu/field-station/research/publications/annual-reports/.

# About Us

## 2019 Highlights

• After nearly 40 years at UWM, Jim Reinartz retired in 2019. Jim served first as Manager, then as Director of the Field Station. Jim's many contributions to the Field Station are too numerous to list here. He is well-known for his work on conservation of natural communities throughout Wisconsin, and for sharing his passion for wetlands and plants with his students and colleagues. Jim enjoyed exploring the Cedarburg Bog and developed an intimate knowledge of the Bog over his many years at the Field Station. We wish Jim the best in his retirement.

• Gretchen Meyer was promoted to Interim Director of the Field Station. Gretchen served as Manager of the Field Station for the past 20 years.

• Peter Dunn and Linda Whittingham were awarded the prestigious Elliott Coues award from the American Ornithological Society. The award recognizes their outstanding and innovative contributions to ornithological research, including their extensive field studies and molecular lab work on tree swallows and common yellowthroats. They have been studying birds at the Field Station for over 20 years.

• Ben Glatzel was hired as the Maintenance Assistant at the Field Station.

• The James and Dorathea Levenson Endowment for Ecology and Field Biology awarded its first two fellowships in 2019, to Wendy Semski and Kane Stratman. The endowment was established in 2018 to provide fellowships to UWM graduate students who are conducting research at the Field Station and/or in the Cedarburg Bog. Dr. James B. Levenson conducted research at the Field Station while working towards his PhD in Botany at UWM (awarded in 1976).

• The Field Station collaborated with the UWM at Waukesha Field Station and the Greene Field Station at Carroll University to obtain a fellowship from the Environmental Data Initiative to support a student to archive long-term datasets.

• The furnace at the farmhouse was replaced. The previous furnace was over 25 years old and had been failing.

• Three roofs at the Field Station were replaced: the roof on the office/teaching building, the roof on the garden shed and the roof on the shed adjacent to the research house.

• Field Methods in Conservation, a semester course taught entirely at the Field Station, was offered for the third time in the Fall semester.

• 36 research projects in 2019.

• Over 13,400 in person-hours of instruction and group use in 2019.

## 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 1964. Research at the Station has produced 415 scientific publications and 152 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 has been designated a National Natural Landmark by the Department of Interior, a Wetland Gem by the Wisconsin Wetlands Association, and an Important Bird Area by the Wisconsin Bird Conservation Initiative. A "Guide to the Natural History of the Cedarburg Bog" serves as an introduction and reference source for researchers and educators using the Bog and is available online (https://dc.uwm.edu/cgi/viewcontent.cgi?article=1110&context=fieldstation_bulletins). 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. As of 2016 Emerald Ash Borer had killed essentially all the mature ash trees in the Bog. Approximately 12% of the trees in the Bog were black ash, accounting for 10% of total tree basal area, and 2% were green ash, 4% of basal area.

**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. Essentially all the white ash in the upland forest are now dead. White ash made 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 is included in the National Natural Landmark designation for the Cedarburg Bog and is also included in the Important Bird Area.

**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 is maintained. Six separate areas in the old fields have been planted with prairie species native to Wisconsin. Controlled burns of the prairie and old-field areas were last conducted in 2016.

**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*), Japanese barberry (*Berberis thunbergii*) 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. However, in 2017 the beetle population appeared to have been reduced and there was more flowering of the purple loosestrife again. 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. FOCB continues to work with grant funding for buckthorn control work in the Bog.

# Research and Teaching Facilities

## General Facilities

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

## Hydrology, Meteorology & Phenology

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

## Animal Ecology & Behavior

- Sound room facility for studies of frog communication and vocalizations
- Live traps & animal holding facilities
- A large array of snake cover-boards
- Extensive arrays of bird nest boxes
- Flying squirrel nest boxes
- Insect collection, small mammal & bird study skins

## Experimental Garden

- 6 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 Mid-west. Up to 150,000 bats of four species (Little brown bats, Big brown bats, Eastern pipistrelles, and Northern long-eared bats) used the hibernaculum. 2015 was the first year that the fungus that causes white-nose syndrome in bats was positively detected at the Neda Mine Hibernaculum. The disease was confirmed in the bat population in 2016, and the population of bats in the mine has declined. The mine is also of geological interest; its cliffs provide an excellent exposure of the Niagara Dolomite and the only accessible exposure of the Neda Iron formation.

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

**Benedict Prairie** - Near Kenosha, is a 6-acre tract of virgin prairie along a railroad right of way that has a remarkably diverse flora. A vascular plant species list for Benedict Prairie has been published in the Field Station Bulletin. Woody plants were cut from the prairie 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 in the spring of 2015 and again on 14 April 2016.

**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. In 2016 the Field Station obtained a grant from the *Southeastern Wisconsin Invasive Species Consortium* to continue eradication of invasive shrubs and garlic mustard in Downer Woods. We completed that funded control project in 2017, and management work in Downer Woods has entered a new maintenance phase requiring substantially less annual effort.

## Field Station Programs

• 36 active research projects conducted at the Field Station in 2019.

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

• 10 papers published during 2019. 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.

• Lists of vertebrates, including birds, mammals, and reptiles and amphibians.

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

• A working map of the Cedarburg Bog basin depth.

• 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.

• Phenological observations on leaf-out and flowering of standard genotypes of 6 species in a phenological garden, and 25 naturally occurring species at the Station since 2001.

• Phenocams for monitoring phenological changes in vegetation. Cameras are mounted both at the Field Station property in Saukville and in Downer Woods on the UWM campus.

• Long-term weather records from a standard US Weather Service weather station and a Bowen-Ratio energy flux monitoring system. Dr. Mark Schwartz' research relating climatic parameters to seasonal development of plants has contributed to this long-term database.

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

• 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 Höbel, 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.

• Monitoring of bat activity levels at the Neda Mine Bat Hibernaculum from 2000-

2019 and of temperatures in the mine since 1997.

The Neda Mine caving crew has exited the mine after collecting temperature data from dataloggers located inside the mine. Left to right: Will Zarwell, Dagmara Antkiewicz, Joe Senulis and Dan Pertzborn. Photo by G. Meyer

• Records of long-term (30 year) research projects conducted by Dr. Charles Weise, on black-capped chickadees and dark-eyed juncos

• GIS developed for the Field Station area.

**Educational Programs**

• Over 13,400 person-hours of instruction and group use in 2019 .

• Nine workshops on topics in natural history.

• Field Methods in Conservation, taught entirely at the Field Station, has been offered in the Fall semester since 2017.

• 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 (uwm.edu/field-station/category/bug-of-the-week/). Bug of the Week has become by far the most visited feature of our website.

• 3 undergraduate student projects.

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

• The Field Station Bulletin, covering various topics related to natural history in southeastern Wisconsin, is available online (https://dc.uwm.edu/fieldstation_bulletins/)

## The Friends of the Cedarburg Bog – 2019

The Friends of the Cedarburg Bog (FOCB) was founded in 2005 to support stewardship, understanding and appreciation of the Bog through land management, preservation, research and education. The FOCB Board of Directors continues to follow and adapt their strategic Action Plan focusing their effort in five areas:

• Strengthen Community Support for the Bog – Develop strong, informed community-based support for sustaining the unique nature of the Cedarburg Bog through a focused outreach effort.

• Expand FOCB's Conservation Impact – Expand the FOCB's area of conservation focus to the Bog's natural boundaries through: (1) sustainable stewardship programs within that perimeter; (2) focused partnerships that work towards landowner commitment to conservation practices.

• Extend the use of the Bog as a Natural History Classroom and Laboratory – Support science-based understanding of the Bog and use its' unique character to foster a sustainable land ethic.

• Be a Good Partner – Establish strong, supporting relationships with our DNR and UWM partners; and also with like-minded organizations that further the FOCB's mission impact.

• Be a Healthy Organization – Have an active, focused, learning and mutually-supportive board and staff, with the competencies and capacity to advance the mission of the FOCB.

Some of the main highlights and challenges for FOCB in 2019 included:

• FOCB continued the Bog Guardian Program. This multi-faceted program is designed to stop the advancement of 4 target invasive plants that are nearly absent from

the Bog area, and that are spread primarily along roadways, before they reach the area. The populations of all 4 target species along roadways have been mapped in a 28 $mi^2$ area surrounding the Cedarburg Bog, and control of the known populations is ongoing. The program also engages neighboring land owners through education and outreach.

• The FOCB is stronger financially than ever due to memberships and private donations. The organization has developed a strategic action plan to look at long-term financial sustainability including building on the endowment.

• The Friends continued to be the primary provider of stewardship of the Cedarburg Bog. FOCB has raised funding to remove buckthorn, an invasive shrub, from over 550 acres of native wetland plant communities. The ambitious goal is to prevent seed production in that treated area by removing buckthorn whenever they grow to near fruiting size. In 2019 the Friends worked at clearing a 26-acre area for a second time.

• The Friends continued to produce their quarterly newsletter, The BogHaunter. Past issues of The BogHaunter can be found on the FOCB website (https://bogfriends.org/boghaunter/).


Dr. Alan Parker led hikers into the Beechwoods in search of mushrooms in September. Photo by Lynn Hertel Campbell

• The FOCB website was completely redesigned in 2019. The new website is more visually engaging and provides more information about the organization.

• FOCB celebrated International Bog Day for the third time in 2019.

• The Friends continued their strong educational programming for the general public with 21 educational events and programs in 2019.

• FOCB continues to support the Field Station's Natural History Workshops through sponsorship of $5,000.

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

## Genetic Structure of a Pitcher Plant Rotifer *Habrotrocha rosa* Metapopulation: DNA Sequence Variations in the *cox1* and *cob* genes

Biane Alforookh and Liane Cochran-Stafira
Department of Biological Sciences, Saint Xavier University, Chicago, IL, cochran@sxu.edu

We are exploring the genetic architecture of a metapopulation of *Habrotrocha rosa*, a bdelloid rotifer found in leaves of the purple pitcher plant *Sarracenia purpurea*. We will employ a rapid extraction procedure for rotifer DNA using hot NaOH and tris-HCL pH5 (HotSHOT method). After sequencing each genetic clone, we will look for variations in the *cox*1 and *cob* genes that mirror the temporal and spatial phenotypic variations observed in this metapopulation.

## Wildlife Monitoring in Southeastern Wisconsin

Gary S. Casper
UWM Field Station, gscasper@uwm.edu

Wildlife monitoring in southeastern Wisconsin, dating back to the 1980s, continued in 2019 with projects on Ozaukee Washington Land Trust properties, private properties, and the Wehr Nature Center. These data inform habitat management and continue to expand regional understanding of wildlife distribution and status. Projects included sampling for breeding birds, mammals, herptiles, and crayfish. In 2019 the second record for Red-backed Vole in Washington County was obtained, and new records for rare Ozaukee County mammals included Long-eared Bat, Southern Flying Squirrel, and Star-nosed Mole. The absence of small bodied hylid frogs (Spring Peeper, Boreal Chorus Frog) was notable on surveys in northern Ozaukee County. These studies are funded by a variety of grants and private donations.

Southern Red-backed Vole (*Myodes gapperi*)

## National Park Service Great Lakes Network Amphibian Monitoring Program

Gary S. Casper
UWM Field Station, gscasper@uwm.edu

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 is now fully implemented in seven National Parks. In 2019 annual data collection continued and we analyzed and reported on 2018 data. Funded by the National Park Service.

## Sound Production in Turtles

Gary S. Casper and Gregory A. Geller
UWM Field Station, gscasper@uwm.edu

We investigated sound production in embryonic turtles in Wisconsin, and discovered that both Northern Map Turtle and Snapping Turtle embryos emit sounds while in the egg. Sound production increases just prior to hatching. This is the first published discovery of this phenomenon.

Gary Casper and Greg Geller in the field

## Field Guide to Amphibian Eggs and Larvae

Gary S. Casper, Thomas G. Anton, and Ryne D. Rutherford
UWM Field Station, gscasper@uwm.edu

We produced a field guide to the eggs and larvae of the amphibians of the western Great Lakes region. The guide provides new identification keys, and species accounts with full color photographs of all life stages, for 23 species including all Michigan and Wisconsin species. This was a National Park Service project, and is being published by Midwest Partners in Amphibian and Reptile Conservation.

## Bioacoustic Monitoring

Gary S. Casper
UWM Field Station, gscasper@uwm.edu

Bioacoustic monitoring for frogs and toads continued throughout the western Great Lakes region in national parks and private preserves, with work in 2019 focused on refinements to data analysis procedures. Development of a bioacoustic monitoring program for breeding birds continued with data collection and analysis throughout Wisconsin and southeastern Minnesota. Additional acoustic bat data was also collected in southeastern Wisconsin. Funding was provided by the National Park Service, the Kohler Foundation, and several private property owners

# Collaborative Native Orchid Conservation and Restoration Project

Melissa Curran[1] and Matt Smith[2]
[1] Stantec Consulting Services, Inc., Melissa.curran@stantec.com
[2]Riveredge Nature Center, msmith@riveredge.us

North America is home to over 200 species of native orchids. Nearly half of these species are under severe threat due to habitat destruction, and many species are likely to become extinct unless action is taken to conserve them and their fungal partners. Promoting efforts to conserve habitats and to restore native orchids where populations have declined will be essential to the future of these fascinating plants. Since 2012, a coalition of partners has focused on native orchid conservation by developing a large-scale, collaborative project addressing threats to native orchid species in Wisconsin with an emphasis on trying to understand their recovery and conservation potential. This project relies on shared resources across a network of partners including nonprofits, local municipalities, federal and state agencies, research institu-

Katrina Degenhardt of Riveredge, Melissa Curran of Stantec, and Christine Bohn of OWLT take measurements on a small population of yellow lady slipper that barely escaped a white tail deer's breakfast. Photo by Matt Smith of Riveredge

tions and private individuals. The project's main objectives are to support regional and national conservation efforts by supplying partner organizations with local genotypes for ex situ propagation, seed and fungal banking, and to advance the science of native orchid restoration through experimental outplantings of lab-propagated orchids in native habitats. Project tasks include investigating the biological requirements of several orchid species by collecting baseline data at reference sites where they occur; collecting seed for propagation experiments; collecting seed and root material for regional banking; identification of suitable outplanting sites; implementation of trial outplantings; and monitoring to evaluate the success of the introduced populations.

Melissa Curran with Stantec pollinating the white lady's-slipper orchid in Kenosha County, Wisconsin. Photo by Melissa Curran.

## Leaf Chlorophyll Estimates of Temperate Deciduous Shrubs During Autumn Senescence Using a SPAD-502 Meter and Calibration with Extracted Chlorophyll

Alison Donnelly[1], Rong Yu[1,2,] Chloe Rehberg[1], Gretchen Meyer[3] and Erica B. Young[4]
[1]Department of Geography, UWM, donnela@uwm.edu, rong.j.yu@gmail.com
[2]School of Natural Resources, University of Nebraska-Lincoln
[3]Field Station, UWM, gmeyer@uwm.edu
[4]Department of Biological Sciences, UWM, ebyoung@uwm.edu

Nondestructive estimates of leaf chlorophyll (Chl) content by hand-held chlorophyll meters such as the Minolta SPAD-502 provide an effective time-efficient method of collecting field data on senescence. However, in order to establish useable relationships between chlorophyll meter readings and actual leaf Chl content species-specific calibration equations are necessary. During the autumn senescence period, we collected SPAD values over a 10-week period (DOY 250 to 312) from 1,044 leaf samples representing both native and non-native temperate deciduous shrub species growing in the wild. Subsequently Chl was extracted from 1 cm diameter leaf discs, incubated at 65°C for 2 hr in 100% Dimethyl sulfoxide and quantified by spectroscopy. Relationships between extracted Chl and SPAD values were established using linear, quadratic and exponential equations. Quadratic functions proved the most reliable fit for the data. Interestingly, non-native species tended to have higher

leaf Chl content and SPAD values but also exhibited higher variability than the native species. The strength ($r^2$) of the SPAD-Chl relationships for these wild shrubs were generally weaker than studies of agricultural or greenhouse-grown plants, but improved over time as both Chl and SPAD values declined. The SPAD meter proved effective at estimating leaf Chl content of native and non-native temperate deciduous shrubs. We report species-specific linear, quadratic and exponential equations which can be applied to these shrub species. SPAD-Chl estimates may potentially be used in future to examine the, often observed, peak in remote sensing vegetation indices in late autumn when upper-canopy trees are leafless.

Alison Donnelly in early spring in Downer Woods observing leaf out of chokecherry

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

Peter O. Dunn and Linda A. Whittingham
Department of Biological Sciences, UWM, pdunn@uwm.edu, whitting@uwm.edu

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 2019 we completed the 23rd 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 Ron Tagye for their assistance with collecting insect and weather data.

## Mate Preferences and Choosiness Vary Independently According to Different Causes of Variation: a Case Study with Eastern Gray Treefrogs (*Hyla versicolor*)

Olivia Feagles and Gerlinde Höbel
Department of Biological Sciences, UWM, ofeagles@uwm.edu,hoebel@uwm.edu

Mate choice is an important cause of sexual selection. Understanding mate choice requires knowledge of the traits involved in generating mate-choice decisions, how they interact with each other, and what proximate mechanisms influence the expression of those traits. Recently, a new study in green treefrogs revealed that mate-choice decisions are likely the outcome of two independent components: preference function (the ranking of attractiveness of prospective mates) and choosiness (the effort invested in mate assessment). To further investigate the independence of female choosiness and preferences, we conducted a series of call playback trials with female eastern gray treefrogs (*Hyla versicolor)* to assess their responses to various call duration stimuli. Additionally, we collected data of potential proximate factors that may influence mate choice trials: body size, body condition, reproductive investment, and salivary hormones. We used testosterone and corticosterone for hormone analyses due to their known roles in mating behavior. Our results show hormonal influences of mate choice in gray treefrogs, but not of size or reproductive investment. We also find that variation in both hormones influences choosiness yet are unrelated to preference. This further corroborates that choosiness and preference functions are independent traits, driven by separate proximate mechanisms, and likely evolving independently from one another. Funded by a Field Research Grant in Herpetology (Society for the Study of Amphibians and Reptiles), a Student Research Grant (Animal Behavior Society) and a Joseph G. Baier Memorial Scholarship (UWM). M.S. Thesis research, Gerlinde Höbel, Major Advisor.

Collecting data after dark at the Field Station

## Fifty Shades of Grey in Treefrogs: Investigating Multimodal Signals in *Hyla versicolor*

Olivia Feagles and Gerlinde Höbel
Department of Biological Sciences, UWM, ofeagles@uwm.edu, hoebel@uwm.edu

Animal signals are often composed of multiple signal modalities, such as vocal, visual, or tactile components. For example, male eastern gray treefrogs are known to employ energetically expensive advertisement calls to entice females, although they also produce two visual traits: gray throats and yellow inner legs. These visual traits are interesting because they (throat/leg) differ in their degree of sexual dimorphism (yes/no), pigment type (melanin/carotenoid), and pigment acquisition (genetically/environmentally). Mating phenotypes and behaviors are often driven by sex hormones (such as testosterone), while stress hormones (such as corticosterone) aid in meeting the associated metabolic demands. To search for connections between visual and acoustic traits, we used hormones to explore mechanisms of covariance between displays. Mechanistic links may provide insight into the possible behavioral implications and intended receivers of these visual displays. Preliminary results found a lack of consistency between hormonal influences on call and color traits, which suggests that they are likely not redundant signals. More specifically, results suggest that thigh color is an indicator of foraging ability, yet throat results were inconclusive. This project improves upon the current understanding of how hormone-driven ornament expression influences trait evolution through sexual selection. Funded by a Field Research Grant in Herpetology (Society for the Study of Amphibians and Reptiles), a Student Research Grant (Animal Behavior Society) and a Joseph G. Baier Memorial Scholarship (UWM). M.S. Thesis research, Gerlinde Höbel, Major Advisor.

A male eastern gray treefrog being released after participating in both color and personality projects. All frogs are always released back at their capture site, which is just adjacent to the field station.

A female eastern gray treefrog collected near the field station that participated in mate choice and personality studies.

## Diverse Microbial Communities Hosted by the Model Carnivorous Pitcher Plant *Sarracenia purpurea*: Analysis of Both Bacterial and Eukaryotic Composition Across Distinct Host Plant Populations

Jacob Grothjan and Erica Young
Department of Biological Sciences, UWM, grothjan@uwm.edu, ebyoung@uwm.edu

The pitcher plant *Sarracenia purpurea* supplements nutrient acquisition through carnivory, capturing insect prey which are digested by a food web of eukaryotes and bacteria. The food web invertebrates are well studied, and some recent studies have characterized bacteria, but detailed genetic analysis of diversity is lacking. This study aimed to compare eukaryotic and bacterial composition and diversity of pitcher communities within and between populations of host plants in nearby but distinct wetland habitats, and to characterize microbial functions across populations, and compare with other freshwater communities. Pitcher fluid was sampled from Cedarburg and Sapa bogs, and community DNA was extracted while rRNA amplicons were sequenced and data processed for community-level comparisons. Bacterial diversity in the small pitcher volume rivaled that of larger aquatic communities. Between pitcher plant populations, several bacterial families were significantly higher in one population. Predicted pitcher bacterial functions were distinct from other freshwater communities, especially for amino acid metabolism, but most functions were similar across all the pitchers. This suggests some bacterial functional redundancy, and that different bacterial composition achieves similar food web processes. Sequencing identified a previously under-appreciated high diversity of ciliates, Acari mites, fungi and flagellates in pitcher communities. Two thirds of eukaryotes were identified as food web inhabitants and a third as prey organisms. Although eukaryotic composition was not significantly different between populations, different species represented core taxonomic groups in different pitchers. Wetland habitat differences may provide distinct taxa available to colonize new pitchers. Eukaryotic composition was more variable than bacterial composition, and there was a poor relationship between bacterial and eukaryotic composition within individual pitchers, suggesting that colonization by eukaryotes may be more stochastic and that bacterial recruitment to pitchers may involve factors other than prey capture and colonization by eukaryotic food web inhabitants. Ph.D. dissertation research, Dr. Erica Young, Major Advisor.

## Understanding Intraspecific Variation in Plant Defense Across Resource Gradients

Phil Hahn[1] and John Maron[2]
[1]University of Florida, hahnp@ufl.edu
[2]University of Montana

A paradigm in the plant defense literature is that defending against insect herbivores comes at a cost to growth, thereby resulting in negative correlations between growth and defense. Although growth-defense trade-offs are common across plant species, there is less support for growth-defense trade-offs within species. Several mechanisms can account for this, but teasing them apart requires explicit comparisons of growth and defense relationships within and among populations, an approach seldom employed. We established a common garden experiment with the perennial native plant bee balm (*Monarda fistulosa*) at the University of Wisconsin-Milwaukee Field Station

(UWMFS). We evaluated genetically-based growth-defense correlations within- and among-populations of a native perennial plant that originate from divergent resource environments. We also surveyed the abundance of insect herbivores (Lepidoptera and Coleoptera) at low-resource sites in Montana and high-resource sites in Wisconsin, including Benedict Prairie and the UWMFS. Insect abundance increased across the resource gradient, indicating selection for higher levels of defense is likely favored in higher resource environments. However, we also found greater genetically-based growth rates for plants from high vs. low resource environments. We found little evidence for ubiquitous growth-defense trade-offs and instead document divergent correlations among various growth and defense traits when examined within versus among populations. We are continuing to study the broader context of the energetic and/or genetic constraints on the joint evolution of these traits and scenarios where growth-defense trade-offs may not be found within species. Funded by the National Science Foundation.

Undergraduate students, Madeline Damon and Jake Palmer, and professor, John Maron, from the University of Montana planting a common garden experiment of *Monarda fistulosa*, bee balm, at the University of Wisconsin-Milwaukee Field Station. May 27 2019. Photo by Phil Hahn.

## Do Signal Types Not Intended for Mate Attraction Influence Mate Choice Decisions?

Gerlinde Höbel
Department of Biological Sciences, UWM, hoebel@uwm.edu

An aspect of animal communication that has received little attention in mate choice studies is that many species possess signal repertoires, i.e., a number of different signal types used in different behavioral contexts and directed at different intended receivers. For example, advertisement signals function primarily in attracting mates, while aggressive signals serve to repel rivals. Nevertheless, the competitive conditions under which mate choice commonly takes place likely result in females being confronted with a combination of signal types. I conducted playback experiments to examine how female eastern gray treefrogs respond to conspecific aggressive calls. I found that females strongly preferred the advertisement over the aggressive call, even when the aggressive alternative had features that normally make calls more attractive (such as longer duration, higher repetition rate and lower frequency). Control experiments and behavioral observations suggest that females do not approach aggressive calls because they treat them as non-relevant noise.

## Suppressing Reed Canary Grass (*Phalaris arundinacea*) via Assisted Succession: a 16-Year Restoration Experiment

Steve Hovick[1], Kattia Palacio-Lopez[1], Kali Mattingly[1], Leah Weston[1], Nate Hofford[1], Logan Finley[1] and James Reinartz[2]
[1]Department of Evolution, Ecology and Organismal Biology, The Ohio State University, hovick.2@osu.edu, palacio-lopez.1@osu.edu, mattingly.66@osu.edu, weston.113@osu.edu, hofford.1@osu.edu, finley.149@osu.edu
[2]UWM Field Station, jimr@uwm.edu

The invasive species reed canary grass *(Phalaris arundinacea*) is widespread throughout North American wetlands. Reed canary grass tolerates a wide range of abiotic conditions, making its management difficult, but because it does not tolerate shade, establishing a canopy of trees and shrubs may be an effective management tool. In the summer of 2019, we conducted follow-up surveys at an experiment initiated in 2003 at the Huiras Lake Natural Area and in 2004 at two smaller sites. Following a range of pre-planting treatments that all included glyphosate herbicide applications in late fall to temporarily impede reed canary grass, 23 species of trees and shrubs were planted at high densities (~1m spacing), with survival recorded over the first two years (one year at the smaller sites). Based on this early phase of the study, we predicted that all pre-planting treatments would be successful over the longer-term and recommended a group of ten trees and shrubs for similar efforts elsewhere (Hovick and Reinartz 2007; Wetlands 27:24-39). Preliminary analyses from 2019 data confirm most of those earlier expectations, at least at Huiras Lake. Reed canary grass dominates the control plots but not the remaining treatments, where abundance in some sampling quadrats is reduced to zero. We find a clear negative relationship between light availability under the tree/shrub canopy and reed canary grass abundance, as well as a negative relationship between reed canary grass abundance and herbaceous species richness. Thus, where a canopy of trees and shrubs was established, the reed

canary grass has declined and other species have increased. These relationships are non-linear, thus we hope to estimate critical thresholds of light availability necessary for reed canary grass reductions and herbaceous community restoration. The 2019 surveys were supported by funds from The Ohio State University; the original planting was funded by the Zoological Society of Milwaukee and the Society of Wetland Scientists.

Steve Hovick and Leah Weston collecting vegetation data in one of the plots that used to be reed canary grass but is now a closed-canopy forest

## White-nose Syndrome Dynamics in Neda Mine Over Winter

Joseph R. Hoyt[1], Kate E. Langwig[1] and A. Marm Kilpatrick[2]
[1]Virginia Polytechnic Institute, jrhoyt@vt.edu, klangwig@vt.edu
[2]University of California, Santa Cruz, akilpatr@ucsc.edu

White-nose syndrome (WNS) has caused massive mortality in bat populations across the eastern United States and is continuing to spread across North America. The disease is caused by the pathogen *Pseudogymnoascus destructans,* which first invaded Wisconsin in the winter of 2013/14. Despite the devastating population impacts suffered by bats across this region, several colonies of bats still persist post-WNS invasion. However, the mechanisms allowing some colonies to persist while others are extirpated remain unknown. Our research seeks to understand the mechanisms underlying population persistence, which can help determine the most effective management strategies that may yield the greatest benefit for each population and species. Our preliminary data from hibernacula across Wisconsin suggest that microclimates within sites are very important for population persistence. Warmer sites experience higher declines and/or complete extirpation whereas bat populations in cooler sites are more likely to persist. Our preliminary results from the past two years at Neda Mine suggests that while bats are exposed to warm temperatures in fall (average bat roosting temperature in November 10.82°±0.81) and have high fungal burdens, the airflow and rapid cooling over the winter (average roosting temperature in March 4.80°±0.76) may be allowing bats to survive in this site which would be otherwise extirpated. Funded by the U.S. Fish and Wildlife Service and the National Science Foundation.

## Detecting Competition at the Level of Individual Fitness: Intraguild Facilitation Between the Larvae of *Metriocnemus knabi* and *Wyeomyia smithii* in *Sarracenia purpurea* Pitchers

Malik Hussain and Liane Cochran-Stafira
Department of Biological Sciences, Saint Xavier University, Chicago, IL, cochran@sxu.edu

Larvae of the pitcher plant mosquito *Wyeomyia smithii* and midge *Metriocnemus knabi* exist as commensals in the leaf phytotelmata of *Sarracenia purpurea.* Midges facilitate the mosquitoes by maintaining high levels of their bacterial food. We have recently documented the consumption of rotifers and ciliates by midge larvae, suggesting the potential for competition for these resources. We suggest that this competition is apparent only when fitness is measured by estimating female egg production via pupal dry weight.

## Species Identification of a *Rhodopseudomonas* Isolate from *Sarracenia purpurea* Pitchers: Role in the Nitrogen Economy of the Pitcher Community

Alejandro Jimenez-Baeza and Liane Cochran-Stafira
Department of Biological Sciences, Saint Xavier University, Chicago, IL, cochran@sxu.edu

*Rhodopseudomonas* is a photosynthetic, facultative anaerobic bacterium that lives in the rain filled pitcher-shaped leaves of the carnivorous pitcher plant *Sarracenia purpurea*. We have isolated an unknown species of *Rhodopseudomonas* from plants at

Cedarburg Bog in SE Wisconsin, and intend to use the Biolog system to determine the species. We believe this bacterium plays a major role in nitrogen cycling in the aquatic community within the leaves; therefore, we will test the organism's ability to fix nitrogen.

## Understanding Ecological and Evolutionary Factors Influencing the Evolution of Plant Mating

Jeffrey Karron[1], Randy Mitchell[2], Dorset Trapnell[3] and Dorothy Christopher[1]
[1]Department of Biological Sciences, UWM, karron@uwm.edu, christod@uwm.edu
[2]Department of Biology, University of Akron, Akron, OH, rjm2@uakron.edu
[3]Department of Plant Biology, University of Georgia, Athens, GA, dorset@uga.edu

Most flowering plants require services of animal pollinators for cross pollination. Pollinator declines due to habitat loss, pesticides, novel pathogens, and climate change threaten both native plant reproduction and agricultural yields. Since seed production is frequently pollen limited, reductions in pollinator abundance and diversity should lower plant reproductive success. However, the severity of the effects of pollinator loss depends on how each pollinator species influences pollen deposition. If members of a guild differ in pollination efficiency, then stochastic events leading to the loss of particular pollinators may result in very different outcomes for a focal plant's reproductive success.

Bumblebees visiting monkeyflowers. Photos by Jeff Karron

In self-compatible species, pollinator declines may influence the quality as well as the quantity of pollen deposited on stigmas. Pollinators may differ in patterns of foraging behavior influencing the extent of self-pollination, the diversity of mates siring progeny within a fruit, and patterns of pollen-mediated gene dispersal. This in turn can strongly influence the genetic structure and long-term viability of flowering plant populations.

Recent declines of bumble bee species in the United States and Europe have generated significant concern since this guild plays a critical role in pollination of native plants and agricultural species. Yet the implications of loss of bumble bee diversity within populations have rarely been studied experimentally, and the effects of bumble bee decline on mating patterns and gene dispersal are completely unexplored. Our research utilizes a novel experimental approach to directly assess the consequences for mating patterns and gene dispersal if an ecosystem undergoes changes in pollinator composition. Funded by the National Science Foundation and the UWM Research Growth Initiative.

# Impact of Changing Snow Cover and Frozen Ground Regimes on Groundwater Recharge

Steven P Loheide II and Katrina A. Rabeler
University of Wisconsin – Madison, Civil and Environmental Engineering, loheide@wisc.edu, rabeler@wisc.edu

Development of seasonal snowpack leads to groundwater recharge associated with spring snowmelt, which often accounts for a large percentage of annual groundwater recharge in the Midwest. The objective of this study is to determine the extent to which freeze and thaw cycles alter groundwater recharge. This study explores the relationship between winter precipitation, the soil thermal regime, and groundwater recharge in the Midwest. Using historical groundwater levels, precipitation, and soil temperature records, we conduct statistical analysis to determine what direct and indirect environmental conditions best explain the relationships between winter precipitation and groundwater recharge. Soil temperature records, groundwater levels, and weather records previously collected from the UW-Milwaukee Field Station are being used as part of this study. By exploring these historical relationships, we aim to better understand how climate variability will impact groundwater recharge in the future. This project is funded by the Wisconsin State Water Resources Research Institute Program through the UW Aquatic Sciences Center.

# The Importance of Well Development When Characterizing the Hydraulic Conductivity of Aquifer Sediments

Cullen Meurer[1], Adam Schmidt[1], Jiyan Hatami, Douglas Cherkauer[1], and Charles Paradis[1]
[1]Department of Geosciences, UWM, paradisc@uwm.edu

The hydraulic conductivity of aquifer sediments within the vicinity of several groundwater monitoring wells was characterized using the slug test method during pre- and post-well development. Slug tests were conducted by rapidly removing a known volume of water from each well followed by monitoring the recharge rate of groundwater to the well. Pre-development slug test data showed strong log-linear trends and good repeatability as evident by reasonably similar times to recharge to 37% of recovery (Fig. 1). The wells were then developed using the surge and purge method to remove fine-grained materials, e.g., silts and clays, within the well screen and the aquifer sediments. Post-development slug test data showed strong log-linear trends, good repeatability, and notably faster times to recharge as compared to pre-development tests (Fig. 1). The hydraulic conductivity of post-developed wells was on the order of 10 to 20 times greater as compared to pre-developed wells and within the range to be expected for the predominant aquifer sediment type, i.e., sands. The results of this study suggested that lack of well development can result in relatively lower estimates of hydraulic conductivity, presumably due to the accumulation of fine-grained materials within and around the well, that may not be representative of the true hydraulic conductivity of the aquifer materials.

Cullen Meurer and Adam Schmidt recording water level measurements at the Cedarburg Bog.

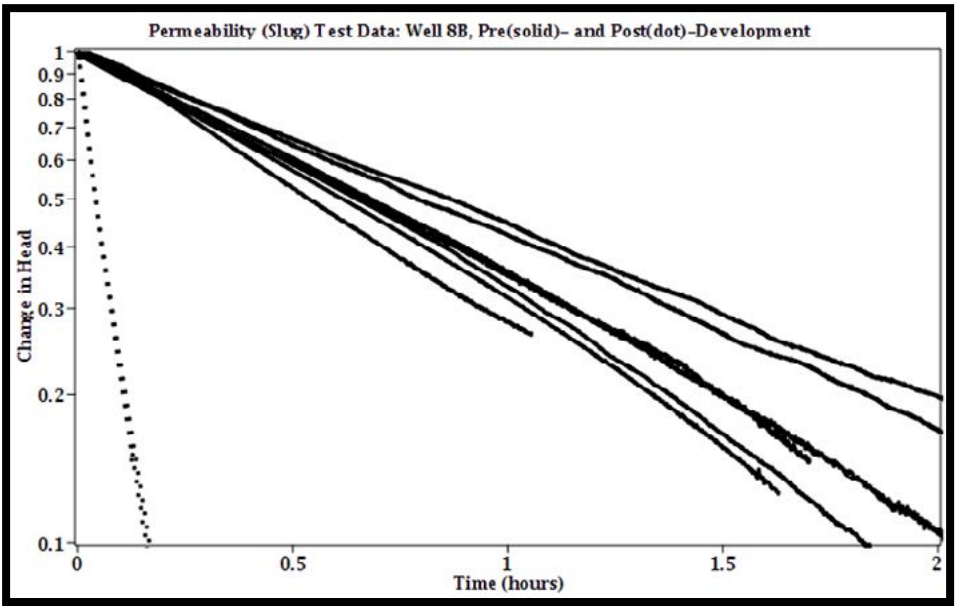



Fig. 1 Change in head (recharge) versus time for slug tests conducted in well 8B during pre-development (solid line) and post-development (dotted line)

## Summary of the 2015 - 2019 Cedarburg Bog Breeding Bird Surveys (WBBA II)

John O'Donnell
Friends of the Cedarburg Bog, johnodonnell132@gmail.com

The fifth and final year of annual systematic surveys of breeding birds in the Cedarburg Bog wrapped up in the summer of 2019. These surveys were part of the state-wide Wisconsin Breeding Bird Atlas II (WBBA II) project. Utilizing Ebird software, the WBBA II provides a digitized compilation of all the breeding bird observations in the state broken down by county and by designated subsections or "blocks" within each county. Each WBBA II observation includes GPS coordinates of the observation and a status assignment of the likelihood of breeding as being either "possible," "probable," or "confirmed" based on the data provided by the observer relative to courtship, copulation, nesting, or fledging evidence.

The Cedarburg Bog covers three "blocks" within Ozaukee County. Given the special conservation significance of the Cedarburg Bog, special emphasis was placed on conducting as thorough a census as possible within the Bog each year from 2015 through 2019. The surveys in the Cedarburg Bog were conducted by a number of well qualified observers covering a wide array of habitats. In 2019, five new species were confirmed as Bog breeders: turkey vulture, yellow-throated vireo, and barn, bank, and cliff swallows. Over the five-year period, 84 species in total were confirmed as breeding in the Bog. The number of "probable" (but not confirmed breeders) totaled 25. In sum, the combined confirmed and probable breeders in the Cedarburg Bog numbered

109 species. Eight additional species were designated as “possible” breeders within the Bog.

American coot hen and chicks

Especially noteworthy over the five year Bog survey was the confirmed or probable breeding of more southerly species at the extreme northern margin of their range, e.g., Acadian flycatcher and hooded warbler (probable) , and more northerly species breeding at the extreme southern margin of their range, e.g., Nashville warbler, northern waterthrush, winter wren, alder flycatcher, red-breasted nuthatch, white-throated sparrow, ruffed grouse (probable), and Canada warbler (probable). Also noteworthy were the species recorded for the first time as confirmed breeders in the Bog: hooded merganser, chestnut-sided warbler, and pine warbler. Breeding bird surveys in the Cedarburg Bog SNA and the Cedarburg Beech Woods were initiated in 1969 with Dr. Charles Weise and have been continuing ever since. The WBBA II data add to this long-term record.

Wild turkey nest

Hooded merganser family on Mud lake

# Wood Duck/Hooded Merganser Nest Box and Owl Nest Box/ Roost Box Project

John O'Donnell
Friends of the Cedarburg Bog, johnodonnell132@gmail.com

With the assistance of volunteers, the Friends of the Cedarburg Bog (FOCB) continue to monitor and maintain 11 duck nest boxes on DNR property within the Bog and 3 duck boxes on private property in the upland woods west of the UWM Field Station. Eleven additional duck boxes have been installed and maintained by private landowners on their own property. All of the boxes on public and private land are GPS located and monitored at least twice a year with maintenance being done at least once a year. In 2019, egg laying occurred in 10 of the 14 duck boxes maintained by FOCB indicating a 71% overall usage rate; however, successful fledging occurred from only six boxes indicating a 43% success rate of duckling production. Explanations of unsuccessful nesting are likely a function of nest abandonment due to predation or a threat of predation or due to the phenomenon of "egg dumping" -- an occurrence where an impregnated hen, being disinclined to incubate for a variety of possible reasons, "dumps" her eggs in a box and then departs.

Four of the six successful nests were by wood ducks, one of the successful nests was that of a hooded merganser, and one successful nest produced both hooded merganser ducklings (estimate 6) and wood ducklings (estimate 4), all overseen by a hooded merganser hen. In this case, it appeared that a hooded merganser hen most likely initiated the nest after which a wood duck hen probably added four eggs to the box while the hooded merganser hen was out of the box feeding. This is not an uncommon occurrence with cavity nesting ducks. Two of the non-used duck boxes were occupied by paper wasps, and one box was occupied by great-crested flycatchers. Of the 10 duck boxes currently maintained by private land owners, only six were accessible at the time of this report due to thin ice conditions. Duck nest activity occurred in four of the six privately maintained boxes (66%); however, successful fledging occurred in only two of the boxes (33%) -- one box producing wood duck offspring and the other hooded merganser offspring.

Two small owl nest boxes and two barred owl nest boxes within the bog are also being monitored and maintained by FOCB at least once or twice a year. One of the barred owl boxes is located on private land; the other three owl boxes are on DNR property. For the eighth year in a row, none of the owl boxes were used by owls for nesting; however, one of the small owl boxes was used for roosting, mostly likely by an eastern screech owl. Contrary to 2018, there was no evidence of any of the boxes being used by northern saw-whet owls as a roost. In late December, an eastern screech owl (gray phase) was flushed from two wood duck boxes when these were opened for maintenance. Given that these two boxes were about 300 yards away from each other and given that the boxes were tended to about three days apart, this may have been the same screech owl. In conclusion, over the last eight years the small owls have only

Barred owl Nest box

occupied the boxes for roosting. There is no indication thus far of any of the owl boxes being used for nesting -- evidence perhaps that natural tree cavities, if amply available, are preferred by local owls over nest boxes.

## Warming Winters and the Regional Implications for the Subnivean Climate

Jonathan Pauli[1], Benjamin Zuckerberg[1], Warren Porter[2] and Brian McMahon[3]
[1]Department of Forest and Wildlife Ecology, University of Wisconsin-Madison, jnpauli@wisc.edu, bzuckerberg@wisc.edu
[2]Department of Integrative Biology, University of Wisconsin-Madison, wpporter@wisc.edu
[3]Operation Fresh Start, Madison, Wisconsin, bmcmahon@operationfreshstart.org

Many plants and animals use the stable environment underneath the snowpack, called the subnivium, as a refuge from harsh winter weather. 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 are assessing 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 set up three microgreenhouses in a conifer stand and collected data on the climate conditions within and outside each greenhouse during winter 2015/16 and winter 2016/17. The data that we measured allowed us to predict the extent, duration, and resiliency of the subnivium habitat. Overall, our work reveals that the subnivium was resilient under an intermediate warming scenario of +3°C. Warming above this level, however, represents a crucial tipping point: at +5°C, we predict an abrupt loss of approximately 200,000 km$^2$ of subnivium habitat and a reduction in duration of one month. These results show that the current trajectory of warming expected for temperate regions of North America will likely lead to the widespread collapse of this critical refuge, and therefore will have severe consequences for winter biodiversity and ecosystem processes. Funded by the National Science Foundation.

## Variation in Throat Pigmentation and Yellow Leg Color in Male Eastern Gray Treefrogs, and Their Influence on Male Mating Success

Richard Pulkowski, Samuel Murray, Emma Czosnek and Gerlinde Höbel
Department of Biological Sciences, UWM, hoebel@uwm.edu

As part of a larger research agenda investigating variability and color change in gray treefrogs, several projects investigated whether variation in throat and leg color of male gray treefrogs is related to male mating success. Over the breeding season (May/July) we took spectrometer measures and digital pictures of the throat and leg area of frogs collected at Byers Pond for our behavioral studies. There are currently two parts of this study, in different stages of completion: (1) The part examining the importance of leg color for male mating success is completed: Yellow leg color is not related to male mating success. (2) The project examining whether throat coloration

is important for male mating success is in the writing stage. Data collection and analysis is completed, and we are working on a manuscript draft. Undergraduate research projects for the first 3 authors, Gerlinde Höbel, faculty advisor.

## Variation in Shrub Phenology Between Native and Invasive Species in an Urban Woodlot

Chloe Rehberg, Alison Donnelly and Rong Yu
Department of Geography, UWM, crehberg@uwm.edu, donnela@uwm.edu, rong.j.yu@gmail.com

Shrub species, both invasive and native, are an important component of temperate deciduous forest ecosystems but are an often-overlooked and under-studied functional group. Shrubs tend to leaf-out earlier than trees in spring and retain their leaves later in autumn thus extending the overall growing season and the carbon uptake period of the forest ecosystem. In this study, a range of 5 native and 3 invasive shrub species were identified in a deciduous urban woodlot, and the phenology monitored over a 3-year period on the University of Wisconsin-Milwaukee USA campus. The aim of this work was to determine any variation in the timing (DOY) and duration (days) of key spring (bud-open, leaf-out, full-leaf unfolded) and autumn (leaf color, leaf fall) phenophases between native and invasive species. Preliminary results revealed interesting findings with buckthorn *Rhamnus cathartica* (an alien invasive species) consistently leafing out later than most native species (wild currant *Ribes americanum*, maple leaf viburnum *Viburnum acerifolium* and nannyberry *Viburnum lentago*) and taking longer to reach full-leaf unfolded. These results will help understand how invasive shrub species may gain a competitive advantage over native shrubs and may help inform future conservation management plans. M.S. Thesis research, Alison Donnelly, Major Advisor

Chloe Rehberg using a hand held chlorophyll meter to estimate leaf chlorophyll.

## Social-ontogenetic Causes of Variation in Mating Signals and Mate Preferences

Rafael L. Rodríguez, Camille Desjonquères and Bretta Speck
Behavioral and Molecular Ecology Group, Biological Sciences, UWM, rafa@uwm.edu, desjonqu@uwm.edu, blspeck@uwm.edu

We are using laser vibrometry and vibrational playback experiments to study the causes of variation in the communication system of *Enchenopa* treehoppers that may promote speciation. *Enchenopa* are plant-feeding insects that communicate with plant-borne vibrational signals. Surprisingly for an insect, we have discovered social and ontogenetic causes of variation in their mating signals and mate preferences. We are currenty testing the hypothesis that offers a simple solution to a problem in the theory of speciation: how distinct packages of ecological and sexual traits originate as

populations diverge. The most straightforward solution (change in a single locus that pleiotropically causes both the use of different environments and reproductive isolation) is often not applicable, because speciation often involves suites of polygenic traits in linkage disequilibrium, which are liable to break up due to gene flow. We are focusing on the hypothesis that *social plasticity generates signal-preference co-divergence*. We are analyzing the form of plasticity in signals and preferences generated by contact between closely related species and contrasting it with the change in signals and preferences that result from genetic hybridization. Funded by the National Science Foundation.

Vlad Melnikov, Nour Aboumar, and Sara Seidita collecting treehopper nymphs for a rearing experiment. Photo by Camille Desjonquères

Dr. Camille Desjonquères testing vibrational recording gear. Photo by Gerlinde Hoebel

## PhenoCam Monitoring of Seasonal Plant Development and Senescence At Downer Woods and the UW-Milwaukee Field Station

Mark D. Schwartz
Department of Geography, UWM, mds@uwm.edu

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.

## Experimental Study of the Mechanisms of Among-Population Variation in Plant Mating Systems

Wendy Semski, Dorothy Christopher and Jeffrey Karron
Biological Sciences, UWM, wrsemski@uwm.edu, christod@uwm.edu, karron@uwm.edu

Most flowering plants are hermaphroditic, yet the proportion of seeds fertilized by self-pollen (selfing rate) varies widely among species, ranging from predominant self-fertilization to mixed-mating to nearly exclusive outcrossing. Selfing rates also vary widely among populations within species, but the evolutionary mechanisms for this among-population variation are not well understood. One possibility is that differences amongst populations may largely be due to ecological context, reflecting differences in pollinator community composition or pollinator foraging behavior. Alternatively, among-population differences in selfing rate may reflect heritable differences in floral traits that influence self-pollen receipt. We are studying the role of ecological and genetic factors influencing selfing rate in monkeyflower (*Mimulus ringens*), a wetland perennial plant native to central and eastern North America. This species varies markedly in floral display size, a trait likely to influence selfing rate since self pollen will often be moved among flowers on the same floral display. Using molecular genetic tools, we quantified selfing rates for 13 natural populations of monkeyflower and found that populations with larger floral displays experienced higher selfing rates. In summer 2019, we established an experimental garden at the UWM Field Station consisting of arrays of plants from 9 natural populations. (See photo on page 30) For 5 days, pollinators were allowed to forage naturally throughout the array. We recorded pollinator movements between flowers, as well as daily floral display size. We are currently raising the progeny produced during this experiment, and by utilizing molecular genetic markers, we will quantify population selfing rate in the experimental garden. If the differences in population selfing rate are similar in the experimental garden and in the natural populations, this will suggest that the differences in selfing are evolved responses, rather than the ecological consequences of display size influencing pollinator behavior. Funded in part by the James and Dorothea Levenson Ecology and Field Biology Fellowship (awarded to Wendy Semski in 2019) and a Prairie Biotic Research Grant. Ph.D. dissertation research, Dr. Jeffrey Karron, Major Advisor

Garden plots and pollinator exclosure for pollination study at the Field Station. Photo by Ron Tagye.

## Variation in Survival After Freezing and Anhydrobiosis and the Effects of These Stresses on Fecundity in the Pitcher Plant Rotifer *Habrotrocha rosa*

Nura Shihadeh and Liane Cochran-Stafira
Department of Biological Sciences, Saint Xavier University, Chicago, IL, cochran@sxu.edu

The bdelloid rotifer *Habrotrocha rosa* lives in the rain filled, pitcher-shaped leaves of the carnivorous pitcher plant *Sarracenia purpurea* where it experiences summer drought and freezing in winter. We hypothesize that *H. rosa* uses anhydrobiosis, a dormant, desiccated state, as an adaptation for surviving the pitcher's unstable habitat. This study explores the temporal and spatial variation in survival and reproductive success after anhydrobiosis and freezing in an *H. rosa* metapopulation.

## A Bivariate Exploration of Among-Female Variation in Mate Preference Functions (*Hyla versicolor*)

Kane Stratman and Gerlinde Höbel
Behavioral and Molecular Ecology Group
Department of Biological Sciences, UWM, stratma8@uwm.edu, hoebel@uwm.edu

Female choice is a widely researched topic of sexual selection. Biologists have characterized both the variation in male mating displays and shape of female preferences for such behaviors across a variety of taxa. A female's *reference functions* represent both the most preferred male trait value and her willingness to accept non-ideal values. In the wild, females are expected to choose based on preferences for multiple aspects of a male display, however the previous research has only measured female-by-female preferences for single traits. In this study we built two preference functions *per individual* (eastern gray treefrogs); one exploring responses to calling duration, and another calling rate. There was considerable variation in general preference shapes, implying that population-level measures in fact hide strongly divergent behaviors. In particular, we found that females are nearly evenly split in their assessment of very rapid calls; many prefer the most extreme rates, while the rest strongly prefer an intermediate value. Knowledge of a female's preference for one trait did not predict her preference for the second. Comparing these bivariate functions to the acoustic distributions of actual recorded males, we found support for directional selection, however the wide range of trait preferences predicts mating success for nearly any signaling male in the wild. M.S. thesis research, Dr. Gerlinde Höbel, Major Advisor.

## Phenological Change among Three Trophic Levels: Birds, Insects and Plants

Jana M. Gedymin Viel
Department of Geography, UWM, jgedymin@uwm.edu

Climate influences the phenology- the timing of biotic life cycle events- of plant and animal species. The impacts of climate change on the phenology of organisms at different trophic levels can vary, resulting in synchrony or asynchrony between organisms and their food sources. Temporal and spatial mismatches due to differing phenological responses between predators and prey can result in cascading asynchronous phenological change within food webs and alter ecosystem dynamics.

By studying the phenology of life events throughout the annual cycles of organisms, researchers are able to better understand how species respond to changes in climate and local weather over time. A species' ability to alter the timing of life-cycle events in response to climate change is not a standalone determinant of success, as organisms do not exist in solitude, but rather, they exist in ecosystems wherein complex multi-trophic interactions occur.

The objective of this study is to examine phenological change at the UWM Field Station and nearby sites in Ozaukee and Milwaukee Counties by investigating indicators of spring phenology among three trophic levels; birds, insects, and plants. Due to the complexity of multi-trophic phenology, this research seeks to first investigate the influence of local weather variables and regional weather patterns on each trophic level in isolation to unveil general trends

related to climate change over time. Then, associations between trophic levels will be assessed in order to examine ecosystem-level phenological change.

This will be accomplished by adding contemporary data to and filling gaps in long-term phenological datasets from a myriad of sources. Historic bird banding data recorded by Dr. Chuck Weise at the UWM Field Station during the late 1960s through the early 1990s will be analyzed for trends in aspects of bird breeding phenology such as the timing of brood patch development in passerine females. Findings will be compared to contemporary bird banding data from current and ongoing research projects in Ozaukee and Milwaukee counties.

In order to investigate indicators of phenological change among insects, this project will utilize and contribute to an aerial insect dataset spanning 19 years, initiated in 1997 at the UWM Field Station by Dr. Peter Dunn and Dr. Linda Whittingham. Similarly, a dataset initiated in 2000 by Dr. Mark Schwartz containing 16 years of observations recorded by Dr. Gretchen Meyer on the spring phenology of several native tree and shrub species at the UWM Field Station will be utilized to investigate phenological change among plants at the bottom trophic level. PhD. dissertation research, Dr. Alison Donnelly and Dr. Mark Schwartz, Major Advisors

## Bat Activity Surveillance and Monitoring at Neda Mine Hibernaculum

J. Paul White, Heather. M. Kaarakka, and Jennifer A. Redell
Wisconsin Department of Natural Resources, Bureau of Natural Heritage Conservation, John. White@Wisconsin.gov

White-nose syndrome (WNS) has spread to 33 states and seven Canadian provinces. The fungus, *Pseudogymnoascus destructans* (Pd), that causes the syndrome has been found in three other states (MS, TX and WY). This deadly disease has and continues to cause massive bat mortality in North America. WNS was confirmed in Wisconsin on March 28th, 2014. As of May 2018, all visited sites in Wisconsin have been confirmed infected with either Pd or WNS. Closely monitoring WNS-affected bat populations is essential to better understand, identify and protect surviving populations.

The bat population of Neda Mine has been inspected (either by internal or external methods) annually for the past nine hibernation seasons and continues to be inspected. Neda Mine was confirmed Pd infected in April of 2015 and the proceeding hibernation season (2016), the Wisconsin Bat Program (WBP) received many public reports from nearby areas that observed aberrant winter bat behavior, almost all reports resulting in the collection of dead bat carcasses. WBP did not receive any public reports of bat activity in or around Neda mine during the winters of 2017-2019.

WBP only inspected the mine through external methods in the 2019 season and was limited to one spring season trapping session. The goal was to trap a sample of bats in the post-hibernation period to 1) understand overwinter weight loss, 2) collect standard measurements (weight; forearm length; species; sex) and 3) mark (with bands) white-nose syndrome survivors in the hopes of recovery at summer sites or in winter sites like Neda Mine.

WBP harp-trapped at two mine entrances for one evening during spring emergence. In total, ten bats were captured in April (2019), all little brown bats (*Myotis lucifugus)* (4 male, 6 female). Of the bats captured that evening, all were aged as adults and banded using an aluminum alloy band with a unique number and letter sequence. The bats examined appeared in good health with no external injuries observed.

## Identification of Microorganisms From Soil at UWM Field Station

Ching-Hong Yang
Department of Biological Sciences, UWM, chyang@uwm.edu

Microorganisms that were isolated from soils were cultured in the medium broth. To classify the bacterial strains, the 16S rRNAs of the isolated bacteria were sequenced. Housekeeping genes were further sequenced on some bacterial strains for classification purposes. The housekeeping genes for multilocus sequence analysis (MLSA) were extracted from genome samples. The maximum likelihood inference was performed using PhyML. The natural compounds produced from the microorganisms were evaluated for their effect on gene expression, such as the expression of c-di-GMP and hrpA encoding genes and evaluated on the growth of *Erwinia* and *Pseudomonas* species. The c-di-GMP is a second messenger of bacteria to coordinate responses to shifting environments. HrpA is a component of the T3SS system in the bacteria. Potential compound candidates are analyzed by mass spectra and nuclear magnetic resonance spectroscopy for their chemical structures. For the future work, we plan to expand our sample areas to other state parks in Wisconsin. Funded by the United States Department of Agriculture and T3 Bioscience LLC.

## MHC Variation is Similar in Little Brown Bats Before and After White-nose Syndrome Outbreak

Xueling Yi[1], Deahn M. Donner[2], Paula E. Marquardt[2], Jonathan M. Palmer[4], Jacqueline Frair[3], Dan Lindner[4] and Emily K. Latch[1]
[1] Department of Biological Sciences, UWM, xyi@uwm.edu, latch@uwm.edu
[2] Northern Research Station, USDA Forest Service, Rhinelander, Wisconsin
[3] Roosevelt Wild Life Station, SUNY College of Environmental Science and Forestry, Syracuse, New York
[4] Northern Research Station, USDA Forest Service, Madison, Wisconsin

Fungal diseases represent an increasing threat to biodiversity worldwide, the conservation of which requires better understanding of host responses to fungal pathogens. White-nose syndrome (WNS), caused by the fungal pathogen *Pseudogymnoascus destructans* (Pd), has driven alarming declines in North American hibernating bats, such as little brown bat (*Myotis lucifugus*). During hibernation, infected little brown bats are able to initiate anti-Pd immune responses, indicating pathogen-mediated selection on the major histocompatibility complex (MHC) genes. However, such immune responses may not be protective as they interrupt torpor, elevate energy costs, and potentially lead to higher mortality rates. To assess whether WNS drives selection on MHC genes in infected bats, we compared the MHC class II *DRB* gene exon 2 in little brown bats pre- (Wisconsin) and post- (Michigan, New York, Vermont, and Pennsylvania) WNS (detection spanning 2014-2015). We genotyped 131 individuals, generating 45 nucleotide alleles translated into 27 amino acid alleles, and observed up to 3 loci (1-5 alleles per individual) of the MHC DRB gene. We observed high allelic admixture and a lack of genetic differentiation both among sampling sites and between pre- and post-WNS populations, indicating no signal of WNS selection on MHC gene in little brown bats. However, post-WNS populations exhibited decreased allelic richness, reflecting effects from bottleneck and drift following rapid popu-

lation declines (see Figure 1, page 35). We propose that mechanisms other than adaptive immunity are more likely driving current persistence of little brown bats in affected regions, and that effective adaptive immunity may take more generations to establish in naturally evolving populations. PhD. dissertation research, Dr. Emily Latch, Major Advisor.

## Monitoring Phenology in a Deciduous Urban Woodlot 2018-2019 Using the Recently Launched VENμS Micro-satellite Data

Rong Yu, Alison Donnelly, Chloe Rehberg
Department of Geography, UWM, rong.j.yu@gmail.com, donnela@uwm.edu, crehberg@uwm.edu

Satellite data have been proven to successfully monitor land surface phenology over space and time. Currently, freely available satellite-derived phenology products either have (i) high temporal resolution but low spatial resolution, such as, MODIS (daily return time; 250m spatial resolution) or (ii) high spatial resolution but low temporal resolution, such as, Landsat (30m; 16-day return time). Accordingly, MODIS or AVHRR phenology products are mainly used in detecting large-scale phenological variation, while, due to its coarse time resolution Landsat is used at a local-scale to detect seasonal peaks. Therefore, there is a growing need for both high spatial and temporal resolution satellite data at a local/regional scale to better understand the relationship between satellite monitoring and ground phenological observations. In this study, we will examine measurements from the VENμS (Vegetation and Environment monitoring on a New Micro-Satellite) satellite which was recently (2017) launched by the Israeli Space Agency and CNES in France. It has a two-day return time coupled with a 5-10 meter spatial resolution. We plan to compare these high-resolution satellite measurements to detailed ground phenological monitoring (including both tree and shrub phenology) in an urban woodlot in Milwaukee, Wisconsin, USA. Three questions will be addressed in this study (i) what exact phenophases correspond to NDVI and EVI determined start, peak, and end of the season? (ii) can VENμS detect variation in shrub phenology especially at the extremes of the growing season? and (iii) how is MODIS MAIAC determined phenology related to this detailed VENμS phenology? We anticipate that the high resolution VENμS data will improve phenological accuracy which in turn could help inform forest management and conservation plans.

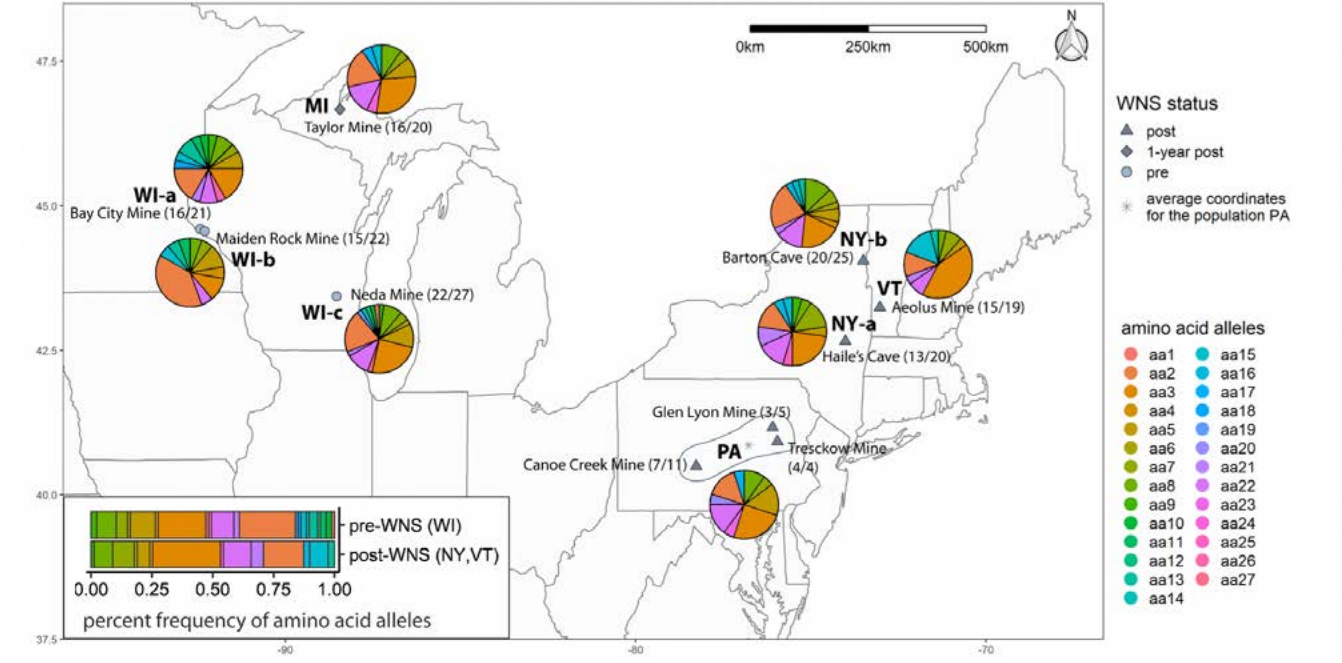



**Fig 1. Distribution of sampling sites and the amino acid alleles.** The ten sampling locations are marked with symbols that indicate WNS infection status and labeled with site names and sample sizes (in parentheses, # successfully genotyped samples / # collected samples). Pie charts indicating percent amino acid allele frequencies were placed around their corresponding sites. Site PA was a combination of three sampling locations with their average coordinates (mapped) used as the population coordinates. A bar chart (bottomleft) shows the percent frequency of amino acid alleles between pre- (WI-a, WI-b, WI-c) and post-WNS (NY-a, NY-b, VT) populations. **(See Yi abstract on page 33)**

# Recent Publications and Theses

## Recent Publications Resulting from Field Station Projects

**Casper, G. S.** 2015**.** New county distribution records for amphibians and reptiles in Wisconsin. Herpetological Review 46(4):582–586.

**Casper, G. S., J. B. LeClere and J. C. Gillingham.** 2015. Natural History Notes. *Thamnophis sirtalis (*Common Gartersnake). Diet/scavenging. Herpetological Review 46(4):653-654.

**Casper, G. S., R. D. Rutherford and T. G. Anton.** 2015. Baseline distribution records for amphibians and reptiles in the Upper Peninsula of Michigan. Herpetological Review 46(3):391–406.

**Fowler-Finn, K. D., J. T. Kilmer, A. C. Hallett and R. L. Rodríguez.** 2015. Variation in signal–preference genetic correlations in *Enchenopa* treehoppers (Hemiptera: Membracidae). Ecology and Evolution 5: 2774–2786.

**Hileman, E. T., J. M. Kapfer, T. C. Muehlfeld and J. H. Giovanni.** 2015. Recouping lost information when mark-recapture data are pooled: a case study of milksnakes (*Lampropeltis triangulum*) in the upper Midwestern United States. Journal of Herpetology 49: 428-436.

**Liu, L., L. Liang, M. D. Schwartz, A. Donnelly, Z. Wang, C. B. Schaaf and L. Liu.** 2015. Evaluating the potential of MODIS satellite data to track temporal dynamics of autumn phenology in a temperate mixed forest. Remote Sensing of Environment 160: 156-165.

**Mathai, P. P., D. H. Zitomer and J. S. Maki.** 2015. Quantitative detection of syntrophic fatty acid-degrading bacterial communities in methanogenic environments. Microbiology 161:1189–1197.

**Meyer, G. A.** 2015. Playing the field. Science 348: 938.

**Monroe, E.M. and H.B. Britten.** 2015. Single-sample estimation of effective population size in several populations of the endangered Hine's emerald dragonfly. Freshwater Science 34: 1058-1064.

**Rebar, D. and R. L. Rodríguez.** 2015. Insect mating signal and mate preference phenotypes covary among host plant genotypes. Evolution 69: 602–610.

**Reichert, M. S. and G. Höbel.** 2015. Modality interactions alter the shape of acoustic mate preference functions in gray treefrogs. Evolution 69: 2384–2398.

**Rodríguez, R. L., M. Araya–Salas, D. A. Gray, M. S. Reichert, L. B. Symes, M. R. Wilkins, R. J. Safran and G. Höbel.** 2015. How acoustic signals scale with body size: common trends across diverse taxa. Behavioral Ecology 26: 168-177.

**Rosenfield, R. N., W. E. Stout, M. D. Giovanni, N. H. Levine, J. A. Cava, M. G. Hardin and T. G. Haynes.** 2015. Does breeding population trajectory and age of nesting females influence disparate nestling sex ratios in two populations of Cooper's Hawks? Ecology and Evolution 5: 4037–4048.

**Rosenfield, R. N., S. A. Sonsthagen, W. E. Stout and S. L. Talbot.** 2015. High frequency of extra-pair paternity in an urban population of Cooper's Hawks. Journal of Field Ornithology 86:144-152.

**Smith, C. E. and G. S. Casper.** 2015. Natural History Notes. *Chelydra serpentina* (Snapping Turtle). Hunting behavior. Herpetological Review 46(2):241-2.

**Whittingham, L.A., C.R. Freeman-Gallant, C.C. Taff and P.O. Dunn**. 2015. Different ornaments signal male health and MHC variation in two populations of a warbler. Molecular Ecology 24: 1584-1595.

**Berg, J. A., G. A. Meyer and E. B. Young.** 2016. Propagule pressure and environmental conditions interact to determine establishment success of an invasive plant species, glossy buckthorn (*Frangula alnus*), across five different wetland habitat types. Biological Invasions 18(5): 1363-1373.

**Casper, G. S.** 2016**.** Geographic Distribution: *Necturus maculosus* (Mudpuppy). USA: Wisconsin: Washington Co. Herpetological Review 47(3): 417.

**Casper, G. S.** 2016. Geographic Distribution: *Hyla versicolor* (Gray Treefrog). USA: Wisconsin: Milwaukee Co. Herpetological Review 47(3): 419.

**Casper, G. S. and Matthew Schmidt.** 2016. Geographic Distribution: *Lithobates catesbeianus* (American Bullfrog). USA: Wisconsin: Green Lake Co. Herpetological Review 47(3): 420.

**Casper, G. S. and R. D. Rutherford.** 2016. Geographic Distribution: *Opheodrys vernalis* (Smooth Greensnake). USA: Wisconsin: Menominee Co. Herpetological Review 47(3): 428.

**Casper, G. S. and P. Kleinhenz.** 2016. Geographic Distribution. *Tropidoclonion lineatum* (Lined Snake). USA: Wisconsin: Dane Co. Herpetological Review 47(3): 429.

**Henschen, A. E., L. A. Whittingham and P. O. Dunn.** 2016. Oxidative stress is related to both melanin- and carotenoid-based ornaments in the common yellowthroat. Functional Ecology 30(5): 749-758.

**Keyes, A.** 2016. Home, sweet nest box: A comparison of detection nethods for the southern flying squirrel (*Glaucomys volans)* in Ozaukee and Washington Counties, WI. Proceedings of The National Conference On Undergraduate Research (NCUR), University of North Carolina.

**Kilkenny, F. F. and L. F. Galloway.** 2016. Evolution of marginal populations of an invasive vine increases the likelihood of future spread. New Phytologist 209: 1773-1780.

**Meyer, G. A., J. A. Senulis and J. A. Reinartz.** 2016. Effects of temperature and availability of insect prey on bat emergence from hibernation in spring. Journal of Mammalogy 97(6): 1623-1633.

**Rutherford, J. L., G. S. Casper and B. Graves.** 2016. Factors affecting predation on Wood Turtle (*Glyptemys insculpta*) nests in the Upper Peninsula of Michigan. Chelonian Conservation and Biology 15(2):181-186.

**Sorin, Y. B., R. J. Mitchell, D. W. Trapnell and J. D. Karron.** 2016. Effects of pollination and postpollination processes on selfing rate in *Mimulus ringens*. American Journal of Botany 103 (8): 1524-1528.

**Whittingham, L. A. and P. O. Dunn.** 2016. Experimental evidence that brighter males sire more extra-pair young in tree swallows. Molecular Ecology 25 (15): 3706-3715.

**Yu, R., M. D. Schwartz, A. Donnelly and L. Liang.** 2016. An observation-based progression modeling approach to spring and autumn deciduous tree phenology. International Journal of Biometeorology 60 (3): 335-349.

**Casper, G.S., C.E. Smith, S.M. Nadeau, and A.Lewanski.** 2017. Geographic Distribution. *Acris blanchardi* (Blanchard's Cricket Frog). USA: Minnesota: Dakota Co. Herpetological Review 48(4):805.

**Fowler-Finn K.D., D.C. Cruz and R.L. Rodríguez.** 2017. Local population density and group composition influence signal-preference relationships in *Enchenopa* treehoppers (Hemiptera: Membracidae). Journal of Evolutionary Biology 30: 13-25.

**Hallett, A.C., R.J. Mitchell, E.R. Chamberlain, and J.D. Karron.** 2017. Pollination success following loss of a frequent pollinator: the role of compensatory visitation by other effective pollinators. AoB PLANTS 9: plx020; doi:10.1093/aobpla/plx020.

**Henschen, A. E., L.A.Whittingham and P.O. Dunn.** 2017. The relationship between blood parasites and ornamentation depends on the level of analysis in the common yellowthroat. Journal of Avian Biology 48:1263-1272.

**Hileman, E.T., R.B. King, J.M. Adamski, T.G. Anton, R.L. Bailey, S.J. Baker, N.D. Bieser, T.A. Bell, Jr, K.M. Bissell, D.R. Bradke, H. Campa, III, G.S. Casper, K. Cedar, M.D. Cross, B.A. DeGregorio, M.J. Dreslik, L.J. Faust, D.S. Harvey, R.W. Hay, B.C. Jellen, B.D. Johnson, G. Johnson, B.D. Kiel, B.A. Kingsbury, M.J. Kowalski, Y.M. Lee, A.M. Lentini, J.C. Marshall, D. Mauger, J.A. Moore, R.A. Paloski, C.A. Phillips, P.D. Pratt, T. Preney, K.A. Prior, A. Promaine, M. Redmer, H.K. Reinert, J.D. Rouse, K.T. Shoemaker, S. Sutton, T.J. VanDeWalle, P.J. Weatherhead, D. Wynn, and A. Yagi.** 2017. Climatic and geographic predictors of life history variation in Eastern Massasauga (*Sistrurus catenatus*): A range-wide synthesis. PLoS ONE 12(2): e0172011. doi:10.1371/journal.pone.0172011.

**Joneson, S. and H. O'Brien. 2017.** A molecular investigation of free-living and lichenized *Nostoc* sp. and symbiotic lifestyle determination. The Bryologist 120(4): 371–381.

**Reichert, M.S. and G. Höbel.** 2017. Frequency channel-dependent selectivity for temporal call characteristics in gray treefrogs, *Hyla versicolor.* Journal of Experimental Biology 220: 1256-1266. doi:10.1242/jeb.152330

**Piaskowski, V.D., J.M. O'Donnell, and G.A. Meyer.** 2017. Bird use of the Cedarburg Bog

Important Bird Area during spring and fall migration. Passenger Pigeon 79 (2): 139 – 161.

**Underhill, V.A. and G. Höbel.** 2017**.** Variation in nocturnal light levels does not alter mate choice behavior in female eastern gray treefrogs (*Hyla versicolor*). Behavioral Ecology Sociobiology 71:151. DOI 10.1007/s00265-017-2386-1

**Ambardar, M., P.O. Dunn and L.A. Whittingham.** 2018**.** Reproductive and foraging success of the Eastern Bluebird (*Sialia sialis*) in relation to vegetation height. Wilson Journal of Ornithology 130(2):362–370.

**Casper, G.S. and R.D. Rutherford.** 2018. Geographic Distribution: *Lithobates catesbeianus* (American Bullfrog). USA: Wisconsin: Shawano Co. Herpetological Review 49(2):282.

**Casper, G.S.** 2018. Geographic Distribution: *Ambystoma maculatum* (Spotted Salamander). USA: Wisconsin: Shawano Co. Herpetological Review 49(2):280.

**Casper, G.S. and R.D. Rutherford.** 2018. Geographic Distribution: *Hemidactylium scutatum* (Four-toed Salamander). USA: Wisconsin: Shawano Co. Herpetological Review 49(2):280.

**Casper, G.S. and R.D. Rutherford.** 2018**.** Geographic Distribution: *Notophthalmus viridescens louisianensis* (Central Newt). USA: Wisconsin: Shawano Co. Herpetological Review 49(2):281.

**Casper, G.S. and R.D. Rutherford.** 2018**.** Geographic Distribution: *Hyla versicolor* (Gray Treefrog). USA: Wisconsin: Shawano Co. Herpetological Review 49(2):282.

**Clark, R.G., D.W. Winkler, R.D. Dawson, D. Shutler, D.J.T. Hussell, M.P. Lombardo, P.A. Thorpe, P.O. Dunn and L.A. Whittingham.** 2018**.** Geographic variation and environmental correlates of apparent survival rates in adult tree swallows *Tachycineta bicolor.* Journal of Avian Biology 49 (6). DOI: 10.1111/jav.01659

**Fowler-Finn, K.D., J.T. Kilmer, D.C. Cruz, and R.L. Rodriguez.** 2018**.** Female mate choice of male signals is unlikely to promote ecological adaptation in *Enchenopa* treehoppers (Hemiptera: Membracidae). Ecology and Evolution 8: 2146-2159.

**Gafvert, U. and G.S. Casper.** 2018. Quality assurance plan for amphibian monitoring in the Great Lakes Network. Natural Resource Report NPS/GLKN/NRR—2018/1713. National Park Service, Fort Collins, Colorado.

**Graham, L.E., M.T. Trest, S. Will-Wolf, N.S. Miicke, L.M. Atonio, M.J. Piotrowski and J.J. Knack. 2018.** Microscopic and metagenomic analyses of *Peltigera ponojensi*s (Peltigerales, Ascomycota). Int. J. Plant Sci. 179(3):241–255.

**Han, W.S., J.P. Graham, S. Choung, E. Park, W. Choi, and Y.S. Kim.** 2018. Local-scale variability in groundwater resources: Cedar Creek Watershed, Wisconsin, U.S.A. Journal of Hydro-environment Research 20: 38-51.

**Henschen, A.E., L.A. Whittingham and P.O. Dunn.** 2018**.** Male stress response is related to ornamentation but not resistance to oxidative stress in a warbler. Functional Ecology 32:1810–1818.

**Karol, K.G., M.S. Alix, R.W. Scribailo, P.M. Skawinski, R.S. Sleith, J.A. Sardina and J.D. Hall.** 2018**.** New records of the rare North American endemic *Chara brittonii* (Characeae), with comments on its distribution. Brittonia 70(3):277-288.

**Minnaar, C., B. Anderson, M.L. de Jager, and J.D. Karron.** 2018**.** Plant-pollinator interactions along the pathway to paternity. Annals of Botany 123: 225–245.

**Murphy, J.C., J.R. Downie, J.M. Smith, S.R. Livingstone, R.S. Mohammed, R.M. Lehtinen, M. Eyre, J.N. Sewlal, N. Noriega, G.S. Casper, T. Anton, M.G. Rutherford, A.L. Braswell and M.J. Jowers.** 2018**.** A Field Guide to the Amphibians and Reptiles of Trinidad & Tobago. Trinidad & Tobago Field Naturalists' Club, Port of Spain, Trinidad and Tobago. R.J. Auguste (managing Editor).

**Rodriguez, R. L., J.E. Wojcinski and J. Maliszewski.** 2018. Between-group variation in *Enchenopa* treehopper juvenile signaling (Hemiptera Membracidae). Ethology Ecology & Evolution 30: 245–255.

**Thompson, K.L., B. Zuckerberg, W.P. Porter and J.N. Pauli.** 2018**.** The phenology of the subnivium. Environ. Res. Lett. 13: 064037.

**Underhill, V.A. and G. Höbel.** 2018**.** Moonlighting? - Consequences of lunar cues on anuran reproductive activity. Acta Oecologica 87: 20-28.

**Underhill, V.A. and G. Höbel.** 2018. Mate choice behavior of female Eastern Gray Treefrogs (*Hyla versicolor)* is robust to anthropogenic light pollution. Ethology 124: 537-548.

**Whitehead, M.R., R.J. Mitchell and J.D. Karron.** 2018. Plant mating systems often vary

widely among populations. Frontiers in Ecology and Evolution 6:38.

**Whittingham, L.A., P.O. Dunn, C.R. Freeman-Gallant, C.C. Taff and J.A. Johnson.** 2018. Major histocompatibility complex variation and blood parasites in resident and migratory populations of the common yellowthroat. Journal of Evolutionary Biology 31:1544-1557.

**Young, E.B., J.R. Sielicki, and J.J. Grothjan.** 2018**.** Regulation of hydrolytic enzyme activity in aquatic microbial communities hosted by carnivorous pitcher plants. Microbial Ecology 76: 885-898.

**Casper, G.S., T.G. Anton and R.D. Rutherford.** 2019. Guide to Amphibian Eggs and Larvae of the Western Great Lakes. National Park Service, Fort Collins, Colorado. 100 pp.

**Christopher D.A., R.J. Mitchell, D.W. Trapnell, P.A. Smallwood, W.R. Semski and J.D. Karron**. 2019. Hermaphroditism promotes mate diversity in flowering plants. American Journal of Botany 106: 1131–1136. https://doi:10.1002/ajb2.1336

**Desjonquères, C., J. Maliszewski, E.N. Lewandowski, B. Speck and R.L. Rodríguez.** 2019. Social ontogeny in the communication system of an insect. Animal Behaviour 148: 93-103.

**Desjonquères, C., B. Speck and R.L. Rodríguez.** 2019. Signalling interactions during ontogeny are a cause of social plasticity in *Enchenopa* treehoppers (Hemiptera: Membracidae). Behavioural Processes 166: 103887. https://doi.org/10.1016/j.beproc.2019.06.010

**Fitzpatrick, M.J., B. Zuckerberg, J.N. Pauli, M.R. Kearney, K.L. Thompson, L.C. Werner II and W.P. Porter**. 2019. Modeling the distribution of niche space and risk for a freeze-tolerant ectotherm, *Lithobates sylvaticus.* Ecosphere, 10 (7):e02788. 10.1002/ecs2.2788

**Geller, G.A., and G.S. Casper.** 2019. Natural History Notes. *Chelydra serpentina* (Snapping Turtle). Hatchling sounds. Herpetological Review 50(4):768–9.

**Geller, G.A. and G.S. Casper**. 2019. Late-term embryos and hatchlings of Ouachita Map Turtles (*Graptemys ouachitensis*) make sounds within the nest. Herpetological Review 50(3):449–452.

**Grothjan J.J. and E.B. Young**. 2019. Diverse microbial communities hosted by the model carnivorous pitcher plant *Sarracenia purpurea*: analysis of both bacterial and eukaryotic composition across distinct host plant populations. PeerJ 7:e6392 http://doi.org/10.7717/peerj.6392

**Huebschman, J.L., S.A. Hoerner, J.P. White, H.M. Kaarakka, K.L. Parise and J.T. Foster.** 2019. Detection of *Pseudogymnoascus destructans* on Wisconsin bats during summer. Journal of Wildlife Diseases 55 (3): 673-677.

**Stratman, K.D. and G. Höbel.** 2019. Opportunity for female choice in the wild is frequently curtailed by low male trait variation in *Hyla versicolor*. Behavioral Ecology and Sociobiology 73(5): 59. https://doi.org/10.1007/s00265-019-2666-z

## Recent Theses

**Kolodziej, Robb C. 2014.** The effect of female quality on mating preferences in Eastern Gray Treefrogs, *Hyla versicolor.* M.S. Thesis.

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

**Hallett, Allysa. 2016.** Consequences of loss of an abundant pollinator: an experimental study. M.S. Thesis.

**Servi, Jason S. 2016**. Natural selection by insect pollinators and seed predators on floral head traits of *Helianthus grosseserratus* (Sawtooth Sunflower). M.S. Thesis.

**Joynt, Emily K. 2017.** Factors controlling diffusive $CO_2$ production and transport in the Cedarburg Bog, Saukville, Wisconsin. M.S. Thesis

**Henschen, Amberleigh E. 2018.** Plumage ornaments signal male physiological quality in common yellowthroats. Ph.D. dissertation.

**Underhill, Victoria. 2018**. Influence of natural and anthropogenic light levels on female preferences in eastern gray treefrogs (*Hyla versicolor)*. M.S. Thesis.

# 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 the Cedarburg Bog in cooperation with the Wisconsin DNR and UWM.

Station which is also part of UWM. G.Meyer attended two strategic planning sessions at the Waukesha station in March 2019. The two stations also worked together to obtain funding from the Environmental Data Initiative to support a graduate student who worked on archiving long-term datasets.

Participants at a UWM at Waukesha Field Station strategic planning meeting tour the property

**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. UWM at Waukesha Field Station**. The Station cooperates with the Waukesha Field

**4. Wisconsin Phenological Society.** G. Meyer serves on the Board of Directors and the Field Station hosts the Annual Meeting each spring.

**5. 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.

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

**10. Hines Emerald Recovery team.** G.Meyer attended a recovery team meeting.

# 2019 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. Nine workshop topics were offered in 2019.

| Workshop | Instructor | Date |
|---|---|---|
| Ecology and Physiology of Plants in Winter | James Reinartz | January 4 & 5 |
| Introduction to Bird Song | William Mueller | February 6 - March 27 |
| Wisdom Sits In Places: Creative Writing About the Natural World | Kimberly Blaeser | April 26 & 27 |
| Wildlife Inventory and Monitoring | Gary Casper | May 31 & June 1 |
| Sedges: Identification and Ecology | Anton Reznicek | June 14 & 15 |
| Vegetation of Wisconsin | James Reinartz | June 17 - 22 |
| Wetland Delineation | Alice Thompson | July 12 & 13 |
| Observation and Discovery in Nature | Suzanne Joneson & Barb Reinhart | July 26 & 27 |
| Aquatic Invertebrates | Gretchen Meyer & Robert Clare | August 2 & 3 |

# Semester Classes

Semester classes taught for UWM by Field Station staff.

| Term | Class | Instructor |
|---|---|---|
| Fall 2019 | Biosci/CES 451, Field Methods in Conservation | Gretchen Meyer |

This course gives students interested in conservation biology and natural area management an opportunity for hands-on learning in the field. Students can go directly from the classroom to natural areas located on the Field Station property, where they practice techniques that have been presented in the lecture. The course filled to its capacity of 20 students.

Tim Vargo demonstrates bird banding techniques for a Friends of the Cedarburg Bog event. Photo by John O'Donnell.

Students in the Wetland Delineation workshop examine plants in a wetland.
Photo by G. Meyer

# Class and Group Use

## Winter - Spring 2019

**Number of Person Hours**

| | |
|---|---|
| UWM - Ecology and Physiology of Plants in Winter workshop | 320 |
| UWM - Introduction to Bird Song workshop | 144 |
| UWM - Creative Writing About the Natural World workshop | 160 |
| Winter Ecology Hike and Friends Chili Dinner | 224 |
| Friends of Cedarburg Bog - Owl Fest | 26 |
| Friends of Cedarburg Bog - Tracking and Learning About Mammals | 51 |
| Friends of Cedarburg Bog - Wood Ducks | 40 |
| Friends of Cedarburg Bog - Glacial Geology | 10 |
| Friends of Cedarburg Bog - Spring Migration at Mud Lake | 18 |
| Friends of Cedarburg Bog - Woodcocks & Frogs | 20 |
| Friends of Cedarburg Bog - Frogs and Maybe Woodcocks | 4 |
| Friends of Cedarburg Bog - Spring Wildflowers | 45 |
| Friends of Cedarburg Bog - Bird Banding | 57 |
| Friends of Cedarburg Bog - Memorial Day Bird Walk | 22 |
| Friends of Cedarburg Bog - Ethnobotany | 36 |
| Friends of Cedarburg Bog - meetings | 184 |
| Ozaukee High School - Ecology Club | 16 |
| Shorewood High School - Watershed Wisdom | 216 |
| Riveredge Nature Center - Field trip for home schoolers | 60 |
| Marian University - Outdoor Adventure Club field trip | 66 |
| Natural Resources Foundation - Woodcocks and Frogs | 60 |
| UW-Arboretum - Field trip | 88 |
| Wisconsin Phenological Society - Annual Meeting | 25 |
| UWM - Candlelight walk (Downer Woods) | 1100 |
| UWM Field Station - Garlic Mustard pull | 15 |
| UWM BioSci 358 - Birds of Wisconsin | 50 |
| UWM GeoSci 401 - General Soil Science (Downer Woods) | 182 |
| UWM - BioSci 310 - General Ecology (Downer Woods) | 1500 |
| **TOTAL** | **4739** |

## Summer 2019

| | |
|---|---|
| UWM - Wildlife Inventory and Monitoring workshop | 304 |
| UWM - Sedges workshop | 320 |
| UWM - Vegetation of Wisconsin workshop | 1240 |
| UWM - Wetland Delineation workshop | 336 |
| UWM - Observation & Discovery in Nature workshop | 320 |
| UWM - Aquatic Invertebrates workshop | 208 |
| Friends of Cedarburg Bog - What's up in the Bog | 15 |
| Friends of Cedarburg Bog - International Bog Day: A Walk and Talk | 39 |
| Friends of Cedarburg Bog - Bog Ethnobotany | 42 |
| Frinds of Cedarburg Bog - Plants from an Evolutionary Standpoint | 33 |
| Friends of Cedarburg Bog - meetings | 68 |
| Wisconsin Wetlands Association - Cedarburg Bog tour | 60 |
| UW-Whitewater - Field Methods in Ecology class field trip | 32 |

| Summer 2019 | Number of Person Hours |
|---|---|
| Natural Resources Foundation - Bog Ethnobotany | 110 |
| Schlitz Audubon Nature Center - Master Naturalist field trip | 165 |
| **TOTAL** | **3292** |

## Fall Winter 2019

| | |
|---|---|
| Friends of the Cedarburg Bog - Mushrooms and Other Fleshy Fungi | 72 |
| Friends of the Cedarburg Bog - Annual Meeting & picnic | 140 |
| Friends of the Cedarburg Bog - A Walk in the Maple-Beechwoods | 42 |
| Friends of the Cedarburg Bog - Owl Prowl | 70 |
| Friends of the Cedarburg Bog – meetings | 82 |
| Advanced Bird Banding class | 240 |
| Lawrence University - Field Ecology class (Neda Mine) | 30 |
| Alverno College - Ecology class | 21 |
| Milwaukee School of Engineering - Physical Hydrogeology class | 36 |
| UW Parkside - Field Methods class | 224 |
| St John's Lutheran Church youth group - Bog tour | 50 |
| University of Illinois College of Medicine - Field retreat | 168 |
| Sierra Club Great Waters Group - Volunteer leaders retreat | 42 |
| University of Illinois-Chicago - Ecology field trip | 750 |
| Urban Ecology Center - Community Science Volunteer field trip | 120 |
| Southeastern Wisconsin Invasive Species Consortium – meeting | 12 |
| Riveredge Nature Center - Christmas bird count | 9 |
| UWM - Geography Department picnic | 60 |
| UWM - Geosciences 463 - Physical Hydrogeology | 126 |
| UWM - Geography 120 - Our Physical Environment | 264 |
| UWM - Geography 450 - Climates of the Past and Climate Change (Downer Woods) | 40 |
| UWM - BioSci 310 - General Ecology (Downer Woods) | 1500 |
| UWM - BioSci/CES 451 - Field Methods in Conservation | 1300 |
| **TOTAL** | **5,398** |
| **TOTAL 2019 Class & Group Use Hours** | **13,429** |

Candlelight event in Downer Woods on the UWM campus

# Meteorological Data for 2019

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.

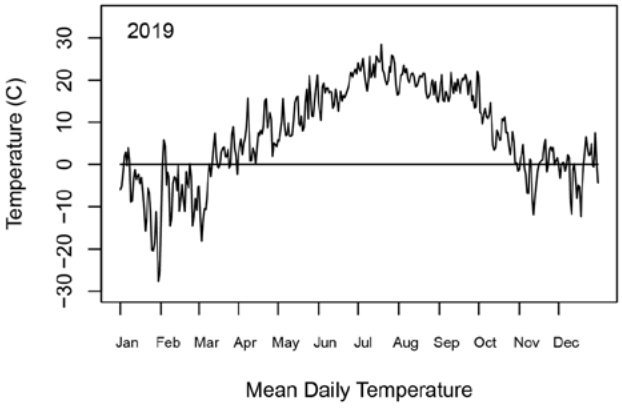
**Maximum Speed (m/s):** Highest mean wind speed during a 30-min period.

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.

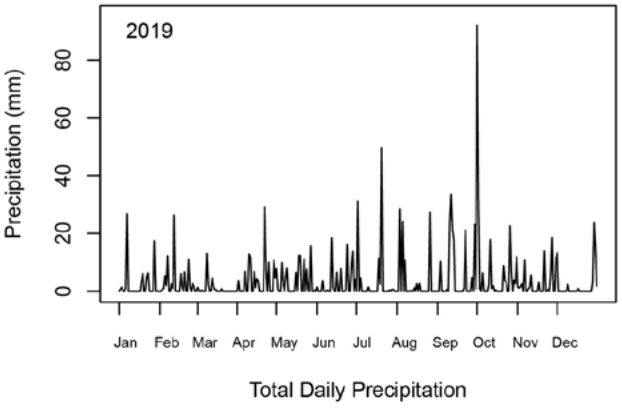
**Meteorological Data for 2019**

| | JAN | FEB | MAR | APR | MAY | JUN | JULY | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Temperature (C°)** | | | | | | | | | | | | |
| Average Daily Maximum | -4.5 | -1.7 | 3.8 | 12.1 | 17.0 | 22.9 | 28.0 | 25.0 | 23.0 | 12.9 | 2.9 | 3.1 |
| Average Daily Minimum | -12.5 | -11.4 | -6.7 | 1.8 | 6.4 | 11.3 | 16.5 | 13.9 | 13.5 | 3.4 | -3.7 | -5.4 |
| Daily Average | -8.2 | -5.8 | -1.2 | 6.7 | 11.7 | 17.2 | 22.4 | 19.5 | 18.0 | 8.0 | -0.4 | -1.2 |
| Highest (Date) | 10.1 (5) | 8.3 (4) | 14.5 (14) | 25.3 (22) | 29.1 (31) | 29.2 (28) | 32.8 (19) | 29.7 (5) | 30.2 (30) | 24.3 (1) | 10.8 (21) | 13.3 (25) |
| Lowest (Date) | -31.7 (26) | -23.0 (19) | -23.0 (4) | -5.4 (1) | -0.2 (4) | 3.7 (3) | 10.3 (9) | 7.1 (1) | 6.8 (5) | -4.7 (31) | -14.8 (12) | -16.9 (18) |
| **Degree Days** | | | | | | | | | | | | |
| Sum at 5° | 0.0 | 0.9 | 8.4 | 77.7 | 206.5 | 365.0 | 538.1 | 448.7 | 390.1 | 116.6 | 1.0 | 4.0 |
| Sum at 10° | 0.0 | 0.0 | 0.0 | 19.5 | 83.1 | 215.0 | 383.1 | 293.7 | 240.1 | 31.6 | 0.0 | 0.0 |
| **Radiation (kW/m$^2$)** | | | | | | | | | | | | |
| Mean | NA[1] | 0.09 | 0.17 | 0.16 | 0.19 | 0.25 | 0.27 | 0.22 | 0.14 | 0.10 | 0.05 | 0.05 |
| Maximum | NA | 0.66 | 0.89 | 0.96 | 0.98 | 1.00 | 1.00 | 0.97 | 0.91 | 0.67 | 0.58 | 0.47 |
| **Relative Humidity (%)** | | | | | | | | | | | | |
| Hour 00-06 mean | 82.7 | 85.2 | 80.6 | 82.6 | 87.0 | 86.1 | 87.6 | 91.6 | 90.4 | 89.8 | 85.6 | 86.5 |
| Hour 06-12 mean | 78.6 | 80.9 | 67.1 | 67.5 | 72.0 | 67.2 | 68.5 | 71.1 | 80.7 | 79.5 | 80.2 | 83.3 |
| Hour 12-18 mean | 69.9 | 75.0 | 55.9 | 58.6 | 60.1 | 59.9 | 57.6 | 59.9 | 70.8 | 67.5 | 70.6 | 73.3 |
| Hour 18-24 mean | 78.5 | 83.2 | 72.9 | 73.5 | 76.0 | 77.8 | 78.7 | 84.2 | 86.0 | 85.2 | 82.2 | 84.7 |
| **Number of Days** | | | | | | | | | | | | |
| Precip. 0.25mm or more | 9 | 17 | 10 | 13 | 14 | 12 | 9 | 7 | 11 | 17 | 14 | 7 |
| Max Temp 32° and above | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Max Temp 0° and below | 22 | 18 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 7 | 8 |
| Min Temp 0° and below | 30 | 27 | 27 | 9 | 1 | 0 | 0 | 0 | 0 | 6 | 24 | 28 |
| Min Temp -18° and below | 9 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Pressure (mbars)** | | | | | | | | | | | | |
| Mean | 1017.99 | 1017.38 | 1018.74 | 1014.02 | 1013.71 | 1014.04 | 1015.82 | 1015.55 | 1016.83 | 1014.85 | 1016.89 | 1014.12 |
| **Precipitation (mm)** | | | | | | | | | | | | |
| Total | 68.7 | 82.9 | 25.5 | 113.5 | 101.2 | 83.4 | 102.5 | 97.9 | 159.3 | 215.9 | 78.5 | 60.6 |
| Greatest (24 hrs) (Date) | 26.8 (7) | 26.4 (12) | 13.0 (9) | 29.2 (22) | 15.7 (27) | 18.6 (12) | 49.7 (20) | 28.5 (3) | 33.5 (11) | 92.0 (1) | 18.6 (27) | 23.8 (29) |
| **Wind** | | | | | | | | | | | | |
| Mean Speed (m/s) | 1.7 | 1.8 | 1.6 | 1.8 | 1.5 | 1.2 | 1.1 | 0.9 | 1.2 | 1.5 | 1.4 | 1.4 |
| Maximum Speed (m/s) | 6.2 | 6.2 | 4.8 | 5.2 | 5.0 | 4.4 | 6.1 | 4.2 | 4.5 | 7.0 | 6.5 | 5.1 |

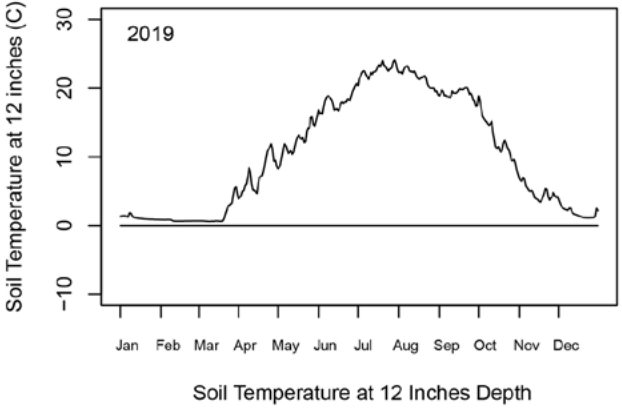
[1]The pyranometer was removed for calibration until Jan 15, 2019.



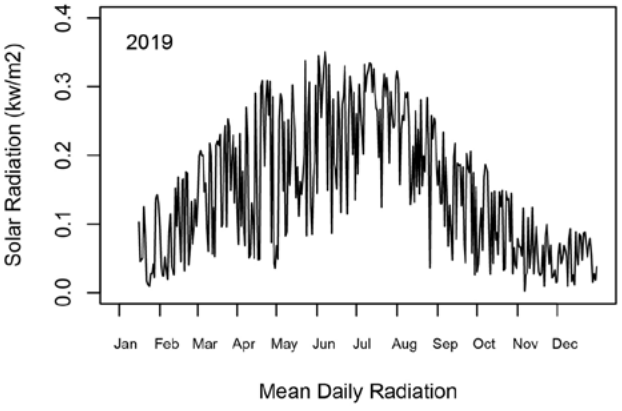

Mean Daily Temperature




Total Daily Precipitation




Soil Temperature at 12 Inches Depth




Mean Daily Radiation

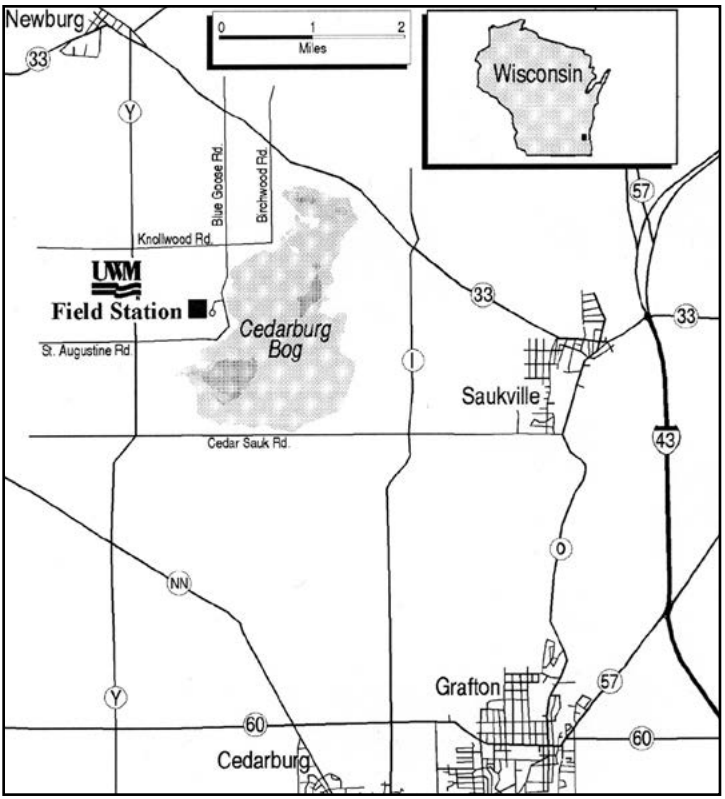
UNIVERSITY of WISCONSIN
UWMILWAUKEE

# Field Station


3095 Blue Goose Road
Saukville, WI 53080

**Phone:** (262) 675-6844
**Fax:** (262) 675-0337

**E-Mail:** fieldstn@uwm.edu
**Web:** www.fieldstation.uwm.edu

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