

MEETING MINUTES

Coordinating Committee Meeting Pennsylvania Cooperative Fish and Wildlife Research Unit

Friday, June 18, 2021
9:00 AM
Held via video conference

Cooperator representatives in attendance: M. Tome, USGS; B. Cardinale, PSU; B. Burhans, M. Schnupp, PGC; T. Schaeffer, A. Shiels, PFBC, S. Williams, WMI; V. Hipkins, USFWS

1. Minutes from June 11, 2020 meeting approved

2. Completed Projects (Summaries in Appendix A)

2.1. Diefenbach

2.1.1. Distribution of predators and their relation to fawn survival

2.2. Wagner

2.2.1. Spatio-temporal drivers of fish growth

2.3. Walter

2.3.1. Minnesota white-tailed deer genetics within chronic wasting disease areas

3. New & Continuing Projects (* Requires approval by Committee; See Appendix B)

3.1. Diefenbach

3.1.1. Harvest and survival rates of hen wild turkeys in Pennsylvania

3.1.2. Genetics of an insular population of bobcats and coyotes

3.1.3. Deer abundance and its relationship to factors that affect forest vegetation conditions

3.1.4. Monitoring movements and habitat use of snowshoe hare

3.1.5. Changes in forest composition through time due to charcoal production for the iron industry, tree harvest, and deer browse

3.1.6. * Integrated population model for wild turkey

3.1.7. * Decision model for fall turkey hunting regulations

3.2. Wagner

3.2.1. Spatial and temporal analysis of endocrine disrupting compounds in surface waters of the Chesapeake Bay Watershed

3.2.2. A macrosystems ecology framework for continental-scale prediction and understanding of lakes

3.2.3. Fish habitat restoration to promote adaptation: resilience of sport fish in lakes of the Upper Midwest

3.2.4. Determining the consequences of land management actions on primary drivers influencing smallmouth bass populations

3.2.5. Changes in stream fish distribution and occurrence in seven National Park Service units of the Eastern Rivers and Mountains Network

3.2.6. Diet composition of invasive flathead catfish in the Susquehanna River Basin: quantifying impacts on native and migratory fishes and recreational fisheries

- 3.2.7. Quantifying the roles of changing watershed conditions and biotic interactions in structuring Pennsylvania stream fish communities
- 3.2.8. Forecasting aquatic invasions in rivers: using riverscapes genetics to inform invasive fish species management at regional scales
- 3.2.9. Quantifying the impacts of climate change on fish growth and production to enable sustainable management of diverse inland fisheries
- 3.2.10. * Scale, Space, and Time: A Unifying Approach to Aquatic Invasions

3.3. Walter

- 3.3.1. The effects of targeted removal of deer groups on the epidemiology of chronic wasting disease in wild white-tailed deer in Pennsylvania
- 3.3.2. Epidemiology of West Nile virus in ruffed grouse (*Bonasa umbellus*)
- 3.3.3. Phase II: Genetic assignment of white-tailed deer to population of origin
- 3.3.4. Optimizing CWD Surveillance: Regional Synthesis of Demographic, Spatial, and Transmission-Risk Factors
- 3.3.5. Parturition timing and calf survival in Pennsylvania elk
- 3.3.6. Linking Genetics to Movements of White-tailed deer to Assist Surveillance for Chronic Wasting Disease
- 3.3.7. * Management Strategies and genetics of deer in Minnesota
- 3.3.8. * Establishing a national tissue and reagents repository for chronic wasting disease
- 3.3.9. * Assessment of movement of prions across the captive-wild interface

4. **Proposed Budget**

5. **Roster of Current Graduate Students and Post-Doctoral Researchers**

5.1. Diefenbach

- 5.1.1. Eva Barr, MS Ecology
- 5.1.2. Phillip Jones, Post-doc

5.2. Wagner

- 5.2.1. Paul McLaughlin, Post-doc
- 5.2.2. Christopher Custer, PhD Ecology
- 5.2.3. Morgan Strum, MS WFS
- 5.2.4. Catherine McClure, MS Ecology

5.3. Walter

- 5.3.1. Avery Corondi, MS WFS
- 5.3.2. Joe Moran, PhD Ecology
- 5.3.3. Kristin Bondo, Post-doc
- 5.3.4. Alberto Fameli, Post-doc

6. **Service on Graduate Committees (other than advisees)**

6.1. Diefenbach

- 6.1.1. Arun Regmi, PhD Forest Science
- 6.1.2. Samuel Bayuzick, MS Soils
- 6.1.3. Katherine Gunderman, MS WFS

6.2. Wagner

- 6.2.1. Nathan Wikel, PhD Statistics

7. Courses and Workshops Taught by Unit Staff

7.1. Wagner

7.1.1. Joint Species Distribution Modeling, spring 2021

7.2. Walter

7.2.1. Applied Spatial Ecology, spring 2021

8. Comments from Cooperators

8.1. **USGS** – Jonathan Mawdsley has been hired as the chief of the Cooperative Research Units. Last year the CRU budget was increased by \$5.6 million that allowed the agency to fill 40 vacant positions. Currently the CRU is conducting a review of its communication process to identify potential ways to improve collaboration and cooperation among partners. Mike Tome will be retiring in December 2021.

8.2. **PSU** – Penn State has centralized the HR process which has led to delays but within the next year those problems should be resolved as everyone becomes familiar with the new process and efficiencies are identified. The budgeting and finance is completely new and is not working, and these problems may be with Penn State for the foreseeable future. The department is undergoing a visioning and planning process. Part of this process will identify new hires in the department. This year 4 faculty are retiring which will be replaced with new hires. In the next year we expect 2 more retirements.

8.3. **PFBC** – Andy Shiels is retiring next week. The agency has created a new position to coordinate efforts to deal with invasive species. Plans for the coming year include having all conservation officer positions filled. Chapter 71 and 73 regulations are being updated.

8.4. **PGC** – Staffing news: Tom Keller is new furbearer biologist which means the section supervisor position will be filled; a quail biologist has been hired; David Stainbrook is the new section supervisor for Deer and Elk; Chris Rosenberry is now oversees game species management; Dan Brauning, head of wildlife diversity section, is retiring in July; Deputy Executive Director of Field Operations is retiring. Chronic wasting disease is a huge issue for the agency made more difficult with the pandemic; however, the agency has been able to continue monitoring.

8.5. **USFWS** – The agency is hoping for budget increase for 2022. The agency is focusing on large landscapes and connectivity, at-risk species as informed by state Wildlife Action Plans, watershed collaboratives, and Chesapeake Bay restoration.

8.6. **WMI** – S. Williams had to leave meeting early

9. Adjourn

10. An Executive Session of the Coordinating Committee will follow immediately after adjournment

10.1. New Projects (noted by asterisk) were approved

Appendix A – Abstracts of Completed Projects

Appendix B – Summaries of New and Continuing Projects

Appendix C – Awards, Publications, and Presentations

Proposed Budget: July 1, 2021 to June 30, 2022

		Indirect costs		
	Amount	Rate	Paid	Waived
Base Funding				
USGS - Cooperative Research Units				
Scientist support (anticipated FY2022)	\$0			
Salaries and benefits (Diefenbach, Wagner, Walter)	\$496,820			
USGS TOTAL	\$496,820			
PA Game Commission				
<u>Diefenbach</u>				
Carry-over from FY2020-21	\$53,788			
Database manager	\$15,000			
Post-doc for Deer-Forest Study	\$22,000			
Operating expenses (travel, publications, etc.)	\$12,000			
Bobcat research	\$6,000			
Rollover to next FY	\$48,788			
SUBTOTAL	\$50,000			
<u>Walter</u>				
Carry-over from FY2020-21	\$44,550			
Deer/Elk genetics	\$5,000			
NanoDrop spectrophotometer	15,000			
Operating expenses (travel, publications, etc.)	\$15,000			
Rollover to next FY	\$59,550			
SUBTOTAL	\$50,000			
PGC TOTAL	\$100,000	0.0%	\$0	\$60,500
PA Fish and Boat Commission				
PA stream fish ecology				
Chris Custer (rollover, saving for out years of PhD support)	\$50,000			
Flathead catfish research				
Field supplies	\$3,000			
Genetics/transcriptomics lab supplies	\$10,000			
Travel	\$2,000			
Operating expenses (travel, publications, etc.)	\$10,000			
PFBC TOTAL	\$75,000	0.0%	\$0	\$45,375
PSU Ecosystem Science and Management				
Administrative assistant (salary and benefits)	\$57,245			
Office expenses and support	\$21,753			
SUBTOTAL	\$78,998			
Waived indirect	\$1,153,121			
PSU TOTAL	\$1,232,119			
Base Funding Total (includes waived indirect)	\$1,903,939			

Proposed Budget: July 1, 2021 to June 30, 2022

		Indirect costs		
	Amount	Rate	Paid	Waived
Gifts, Grants, Contracts				
Deer-Forest Study - Diefenbach - PGC project 30	\$123,685	0.0%	\$0	\$74,829
Deer-Forest Study - Diefenbach - DCNR	\$156,000	0.0%	\$0	\$94,380
Deer-Forest Study - Diefenbach - USGS RWO 99	\$52,969	15.0%	\$7,945	\$24,101
Snowshoe hare - Diefenbach - PGC project 40	\$88,574	0.0%	\$0	\$53,587
Wild Turkey Bayesian model - Diefenbach - PGC project 44	\$163,808	0.0%	\$0	\$99,104
CWD targeted removal - Walter - PGC project 31	\$51,232	15.0%	\$7,685	\$23,311
West Nile Virus Grouse - Walter - PGC project 34	\$42,459	0.0%	\$0	\$25,688
Genetic assignment - Walter - PGC project 39	\$75,392	0.0%	\$0	\$45,612
Decision support - Miller - RWO 98 - USGS	\$157,626	15.0%	\$23,644	\$71,720
Ches Bay project - Wagner - RWO 94 - USGS	\$115,000	15.0%	\$17,250	\$52,325
Flathead catfish genetics - Wagner - RWO 95 - USGS	\$125,000	15.0%	\$18,750	\$56,875
Stream fish - Wagner - PA Sea Grant	\$50,000	0.0%	\$0	\$30,250
NPS streams - Wagner - NPS	\$72,947	17.5%	\$12,766	\$31,367
Macrosystems Ecology - Wagner - NSF	\$38,119	60.5%	\$23,062	\$0
Optimizing CWD surveillance - Walter - Cornell University	\$34,984	0.0%	\$0	\$21,165
Elk parturition and calf survival - Walter PGC project 41	\$277,615	0.0%	\$0	\$167,957
Linking Genetics to Movements - Walter - RWO 96 - USGS	\$111,907	15.0%	\$16,786	\$50,918
Mgt strategies/genetics in MN - Walter - USDA/MN DNR	\$50,000	60.5%	\$30,250	\$0
Establishing tissue repository - Walter - RWO 100 - USGS	\$117,548	15.0%	\$17,632	\$53,484
Movement of prions at captive/wild interface- Walter - USDA	\$139,747	10.0%	\$13,975	\$70,572
Gifts, Grants, and Contracts Total	\$1,737,317		\$189,745	\$1,047,246
Grand Total (less waived overhead)	\$2,488,135			

APPENDIX A - Completed Projects

2.1.1 Distribution of predators and their relation to fawn survival

Duane Diefenbach (co-PI), David Miller (co-PI), Asia Murphy (Ph.D. Ecology)

[citation: Murphy, A. M., D. R. Diefenbach, M. Ternent, M. Lovallo, D. Miller. 2021. Threading the needle: How humans influence predator-prey spatiotemporal interactions in a multiple-predator system. *Journal of Animal Ecology*. <https://doi.org/10.1111/1365-2656.13548>]

Perceived predation risk and the resulting antipredator behavior varies across space, time, and predator identity. Communities with multiple predators that interact and differ in their use of space, time of activity, and hunting mode create a complex landscape for prey to avoid predation. Anthropogenic presence and disturbance have the potential to shift interactions among predators and prey and the where and when encounters occur. We examined how white-tailed deer (*Odocoileus virginianus*) fawn spatiotemporal antipredator behavior differed along an anthropogenic disturbance gradient that had black bears (*Ursus americanus*), coyotes (*Canis latrans*), bobcats (*Lynx rufus*), and humans present. We quantified 1) spatial co-occurrence in species distributions, 2) temporal overlap across the diel cycle, and 3) spatiotemporal associations between humans, bears, coyotes, bobcats, adult male deer, and fawns. We also examined how deer vigilance behavior changed across the anthropogenic disturbance gradient and survey duration. Anthropogenic disturbance influenced spatiotemporal co-occurrence across multiple scales, often increasing spatiotemporal overlap among species. In general, species' spatial co-occurrence was neutral or positive in anthropogenically disturbed environments. Bears and fawns, coyotes and adult male deer, and bobcats and fawns all had higher temporal overlap in the agriculture-development matrix sites. In addition, factors that influenced deer vigilance (e.g., distance to forest edge and predator relative abundance) in the agriculture-development matrix sites did not in the forest matrix site. By taking into account the different antipredator behaviors that can be detected and the different scales these behaviors might occur, we were able to gain a more comprehensive picture of how humans reduce available niche space for wildlife, creating the neutral and positive spatiotemporal associations between species that studies have been seeing in more disturbed areas.

2.2.1. An investigation into the role of groundwater as a point source of emerging contaminants to smallmouth bass in the Susquehanna River basin

Tyler Wagner (PI), Vicki Blazer (co-PI, USGS), Kelly Smalling (co-PI, USGS), Megan Kepler (co-PI, PSU) [citation: Thompson, T.J., M.A. Briggs, P.J. Phillips, V.S. Blazer, K.L. Smalling, D.W. Kolpin, T. Wagner. 2020. Groundwater discharges as a source of phytoestrogens and other agriculturally derived contaminants to streams. *Science of the Total Environment*]

Groundwater discharge zones in streams are important habitats for aquatic organisms. The use of discharge zones for thermal refuge and spawning by fish and other biota renders them susceptible to potential focused discharge of groundwater contamination. Currently, there is a paucity of information about discharge zones as a potential exposure pathway of chemicals to stream ecosystems. Using thermal mapping technologies to locate groundwater discharges, shallow groundwater and surface water from three rivers in the Chesapeake Bay Watershed, USA were analyzed for phytoestrogens, pesticides and their degradates, steroid hormones, sterols

and bisphenol A. A Bayesian censored regression model was used to compare groundwater and surface water chemical concentrations. The most frequently detected chemicals in both ground and surface water were the phytoestrogens genistein (79%) and formononetin (55%), the herbicides metolachlor (50%) and atrazine (74%), and the sterol cholesterol (88%). There was evidence suggesting groundwater discharge zones could be a unique exposure pathway of chemicals to surface water systems, in our case, metolachlor sulfonic acid (posterior mean concentration = 150 ng/L in groundwater and 4.6 ng/L in surface water). Our study also demonstrated heterogeneity of chemical concentration in groundwater discharge zones within a stream for the phytoestrogen formononetin, the herbicides metolachlor and atrazine and cholesterol. Results support the hypothesis that discharge zones are an important source of exposure of phytoestrogens and herbicides to aquatic organisms. To manage critical resources within the Chesapeake Bay Watershed, more work is needed to characterize exposure in discharge zones more broadly across time and space.

2.3.1 Minnesota white-tailed deer genetics within chronic wasting disease areas. David Walter, Chris Jennelle (Minnesota DNR), Michelle Carstensen (Minnesota DNR). Funding by the Minnesota Department of Natural Resources

Minnesota has been experiencing various occurrences of chronic wasting disease in white-tailed deer for last decade in wild and captive white-tailed deer. The origin of the disease in the state is largely unknown, however, there are concerns for spread and transmission north into previously disease-free areas from the core areas in southeastern Minnesota. Landscape genetics has become a powerful tool to assess movement of deer by inferring shared ancestry implies some form of movement of deer between subpopulations. This information is not known for the core of chronic wasting disease in Minnesota and also not known across the state with diverse habitats and landscape composition that deer occupy. The objectives of this project are to conduct genetic analysis testing on up to 625 wild white-tailed deer muscle samples received from Minnesota during routine disease monitoring protocols. Testing will include a microsatellite (msats) panel on the 11 optimal white-tailed deer msats as determined by a recent study. Also, testing will include forward and reverse DNA sequencing of mitochondrial DNA (mtDNA), and prion protein gene (PRNP) analysis for codons 95, 96, and 116. The results will provide details on separate components of shared ancestry (11 microsatellite marker genotypes and mtDNA haplotypes) and susceptibility to chronic wasting disease (PRNP genotypes at codons 95, 96, 116) for all 625 deer.

APPENDIX B – New (*) and Continuing Projects

3.1.1 Harvest and survival rates of hen wild turkeys in Pennsylvania. Duane R. Diefenbach, Mary Jo Casalena (PGC), Paul Fackler (NCSU), Funded by PGC, Pennsylvania Chapter NWTF, Alabama Chapter NWTF.

We have been working to incorporate the decision model for making recommendations for the fall turkey season into the PGC's decision making process. A manuscript that we intend to submit to Wildlife Monographs summarizes the results of the hen turkey study, the integrated population model we developed, and the decision model. The manuscript is nearly completed for internal approvals before being submitted to the journal.

3.1.2 Genetics of an insular population of bobcats and coyotes. D. Diefenbach. L. Hansen (LANL), C. Miller-Butterworth (Penn State–Beaver), D. Hoffman (NPS), J. Jordan (Kiawah Island).

A manuscript was published documenting the loss of genetic diversity in the bobcat population over the past 30 years (Miller-Butterworth et al. 2021). We have verbal support from the NPS to translocate bobcats to the island to restore genetic diversity so we have begun discussions with Penn State IACUC on animal handling requirements. Once we know the costs of conducting translocations we will seek funding opportunities.

3.1.3 Deer abundance and its relationship to factors that affect forest vegetation conditions. Eva Barr, D. Diefenbach, M. McDill, P. Drohan, C. Rosenberry (PGC), E. Just (DCNR). Funding provided by PGC and DCNR Bureau of Forestry.

Amanda Van Buskirk (MS Ecology) defended her thesis in summer 2020 and published her chapter on how size and shape of DMAP units affect the ability to reduce deer densities (Van Buskirk et al. 2021). She found that DMAP areas should be at least 5 square miles to have a high probability of reducing deer densities within 5 years.

Eva Barr was recruited as a new graduate student (MS Ecology) to study how environmental factors (soil conditions, slope/aspect, deer herbivory, etc.) explain the distribution of plants used to monitor the effects of deer herbivory. Her work will build on Danielle Begley-Miller's research (PhD WFS) that found soil conditions explained most of the variation in occurrence across the oak-hickory study areas. Eva will be looking at both the northern hardwoods and oak-hickory forest types.

3.1.4 Snowshoe hare movements and habitat use. D. Diefenbach, A. Church, E. Boyd (PGC).

One technician resigned to take a graduate research assistantship and I have been working to hire a replacement. The Work Plan was amended to extend the project through June 2022. The Unit was funded by the PGC to support technician salary and vehicles and will provide databases of snowshoe hare locations and vegetation sampling.

3.1.5 Changes in forest composition through time due to charcoal production for the iron industry, tree harvest, and deer browse. P. Drohan, M. McDill, D. Diefenbach, S. Bayuick

Throughout the northeastern United States and Europe, relic charcoal hearths (RCHs) are more regularly being discovered in proximity to furnaces used for iron or quick-lime production; charcoal was used as a primary fuel source in the furnaces. RCHs have been found across parts of Europe and Connecticut, USA in different hillslope positions, on vary degrees of slope and aspect, all of which can be a factor affecting the shape of the RCH. Their usage for charcoal production varied with the time period, furnaces were in operation with some hearths being used once and older ones (such as in Europe) being used multiple times. RCHs across the northcentral Appalachians, USA have been minimally investigated, thus determining where they occur on the landscape, their shape, and their morphologic positions will be useful in discerning their effect on surface hydrology and soil development. Our study focuses on developing a repeatable process for: finding RCHs and quantifying how RCHs may alter surface hydrology. We used a combination of processed LiDAR data to create hillshades, and slope gradients to visualize RCHs. A total of 6,758 hearths have been digitized across three study areas that reflect different historical time periods of construction and environments. We hypothesize that the construction of RCHs can alter the surface hydrology of their surrounding environments. To fully quantify the landscape-level effects of RCHs, a subset of the total was created to fully digitize the RCHs' area. The RCH was broken into their rim and platform components. A topographic wetness index (TWI), and SAGA wetness index (SWI) was created for two study areas in order to quantify surface hydrology effects. We found that RCH platforms have a significantly higher TWI and SWI than the rim counterparts indicating that the platform is wetter than the RCH outer rims. Geomorphic position was found to not effect wetness. Using field measured volumetric water content, we found that as distance from the center of the hearth increases, the drier the soil becomes. Using a combination of GIS flow path analysis, and RCH geometry, standardized ellipses using the axis of local RCHs and the mean area of the total RCHs were created to understand the upslope (control) and downslope (experiment) effects of hearths on the surface hydrology. Preliminary analysis indicates that downslope positions from RCHs are drier than upslope positions and that there is a significant difference in the relationship between slope position and distance from an RCH and the corresponding TWI and SWI values. Future research will address the effect of slope position and distance to quantify the effect of RHCs on surface hydrology. Furthermore, the soil chemical changes from RCH creation and the increase moisture may increase the habitat for rare species of both plants and animals that otherwise would not be present. Understanding the extent of the impact human activity can have on various ecosystems can help forest managers, conservationists, pedologists, and climatologists better adapt their management or research pursuits within a specific environment to prepare for future changes, natural or anthropogenic.

3.1.6. * Integrated population model for wild turkey D. Diefenbach, F. Buderman (PSU)

An integrated population model (IPM) has been developed to estimate turkey population size by WMU, which requires band-recovery data of males, spring and fall harvest estimates by sex-age class (Game Take Survey and report cards), and reproductive rates (summer sighting survey). The IPM has been demonstrated to provide population estimates as well as derive important

parameters that aren't monitored with data (e.g., fall harvest rates of females and poults). However, the IPM has only been implemented in a spreadsheet to show proof of concept. Developing the IPM in a Bayesian framework using Markov Chain Monte Carlo (MCMC) methods provides multiple advantages: 1) the IPM will provide measures of precision of estimated population parameters, 2) the model can be directly integrated with databases managed by the Pennsylvania Game Commission (PGC), and 3) the model can evaluate the effects of different levels of sampling effort (e.g., how increasing the number of turkeys leg banded affects precision of population estimates). A post-doc will be hired to perform this work.

3.1.7. * Decision model for fall turkey hunting regulations D. Diefenbach, F. Buderman (PSU)

The Pennsylvania Game Commission (PGC) has identified two objectives when setting fall hunting seasons for wild turkey: (1) maximize spring male population, and (2) maximize fall hunting opportunity. These objectives, however, are competing and maximizing both is impossible because greater fall season lengths will increase female harvest rates and lead to reduced male abundance via lower recruitment. Consequently, an optimization of these objectives is possible only by considering the population dynamics of turkeys and the relative value stakeholders place on male abundance and fall hunting season opportunity.

We have proposed a 4-year project that will support a Ph.D. candidate to address the following problems with setting fall turkey seasons: (1) Estimate the effect of limiting the type of sporting arms in fall hunting seasons on female harvest rates and how season length AND type of sporting arm could be incorporated into a decision model for setting fall turkey hunting seasons. This question could be evaluated by looking at catch-per-unit-effort before and after rifles were legal, and setting up an experiment by changing sporting arm regulations among WMUs; (2) Evaluate the benefit finalizing fall hunting seasons in September by estimating any increased opportunity in season length and spring harvest when fall regulations are finalized in September instead of January due to reduced uncertainty when making a decision in September, conducting a social survey of turkey hunters to evaluate the tradeoffs of January versus September decisions and quantify the value to stakeholders of the different decision timeframes, and working with decision makers (PGC executive office, biologists, law enforcement, and Board of Commissioners) to identify the tradeoffs and regulatory issues related to finalizing seasons in January versus September. This would be accomplished using a combination of surveys and focus groups.

We have proposed a 2-year project that will support an M.Sc. student to address the following questions: (1) How does turkey habitat-use and movement behavior vary as a function of the landscape and weather patterns?; (2) What is the relationship between turkey habitat-use and movement behavior and individual reproduction and survival? Some of the research on habitat use and movements could be extended to account for disease prevalence.

3.2.1 Spatial and temporal analysis of endocrine disrupting compounds in surface waters of the Chesapeake Bay Watershed Tyler Wagner (PI), Vicki Blazer (co-PI, USGS), Kelly Smalling (co-PI, USGS)

This project that investigate the spatial and temporal variation of contaminants of emerging concern (CEC's) within the surface waters of rivers in the Chesapeake Bay watershed. The project will synthesize and analyze over four years of existing data that were collected by the United State Geological Survey (USGS) throughout the Chesapeake Bay watershed. Specifically, this project will focus on the role that extreme flow and storm events may have on the prevalence and concentration of CEC's in surface water, as well as any possible connections between nutrient levels and CEC's in surface water. Finally, we will conduct a spatial analysis to explore the role that different land cover types have on river CEC composition and concentrations. The proposed project will use Bayesian statistical modelling to meet the study objectives. The goals of this research are to increase the knowledge of the spatiotemporal dynamics of CEC's to better inform management of the Chesapeake Bay watershed. Specifically, this information will help inform land management, restoration and protection of the Chesapeake Bay.

3.2.2 A macrosystems ecology framework for continental-scale prediction and

understanding of lakes Tyler Wagner (co-PI), Patricia Soranno (PI, MSU), Kendra Cheruvilil (co-PI, MSU), Emily Stanley (co-PI, Univ. WI), Noah Lottig (co-PI, Univ. WI), Ephraim Hanks (co-PI, PSU), Erin Schliep (co-PI, Univ. MO), Pang-Ning Tan (co-PI, Univ. MSU), Jiayu Zhou (co-PI, Univ. MSU)

In the past decade, our understanding of how inland waters influence regional, continental, and global biogeochemical cycles has fundamentally changed. We have moved from discounting their contributions, to now recognizing these ecosystems as significant hotspots for the storage and transformation of nitrogen, phosphorus, and carbon. This realization has come about through careful and labor-intensive collection, integration, and synthesis of often-scattered data sources, combined with a variety of different approaches to extrapolate site-level measures to unsampled sites across regions and continents. Today, although this view of the role of inland waters in large-scale cycling is supported by numerous studies, substantial gaps in our understanding remain. Estimates for the same flux (e.g., organic carbon burial in lakes) often differ substantially among studies. Further, most attempts to quantify continental or global fluxes or pools come with caveats regarding the often high– and often unknown– uncertainty associated with these estimates. To better understand the role of inland waters in macroscale nutrient cycling, new approaches are needed to reduce uncertainty in extrapolating site-level estimates to larger geographical scales. The overarching goal of this research is to understand and predict nutrient patterns for ALL continental US lakes to inform estimates of lake contributions to continental and global cycles of nitrogen (N), phosphorus (P), and carbon (C), while also providing locally valuable information about conditions in unsampled lakes.

3.2.3 Fish habitat restoration to promote adaptation: resilience of sport fish in lakes of the Upper Midwest Tyler Wagner (co-PI), Gretchen Hansen (PI, Univ. MN), Jordan Read (co-PI,

USGS), Erin Schiep (co-PI, Mizzou), Zach Feiner (co-PI, WI DNR), Catherine Hein (co-PI, WI DNR), Pete Jacobson (co-PI, MN DNR), Joe Nohner (co-PI, MGLP, MN DNR), Samantha Oliver (co-PI, USGS), Kevin Wehrly (co-PI, MI DNR), Abigail Lynch (co-PI, USGS NCAC)

Fish responses to climate change are heterogeneous across the landscape of lakes. Local habitat conditions and the abundance of other species can influence fish responses, and by manipulating these factors, fish managers may increase resilience of certain populations to warming. We propose to quantify fish responses to climate change in lakes throughout the Midwestern United States, and to identify factors that explain heterogeneity in how fish populations respond. Our objectives are to: (1) Develop statistical models of the relative abundance of multiple species of fish in lakes throughout the Upper Midwest; (2) Quantify relationships between environmental conditions, species interactions, and the abundance and recruitment of managed fish; (3) Predict abundance and recruitment of multiple fish species under future scenarios of climate change; and (4) Identify and communicate priority lakes for implementing habitat protection and restoration actions. We will develop joint species distribution models that quantify dependencies between multiple fish species and their environment. We will collate fish relative abundance and habitat data from the 8 state fisheries management agencies of our study region (Illinois, Indiana, Iowa, Michigan, Minnesota, North Dakota, South Dakota, and Wisconsin). Target species will include walleye, yellow perch, black bass, northern pike, cisco, and bluegill to span a range of thermal preferences and management strategies. We will simulate water temperature conditions under contemporary (1979-2019) and future (late 21st century) climate conditions. We will quantify relationships between multiple fish species abundance and recruitment, lake characteristics, and climate. The models will be used to assess how multiple fish species respond to water temperature and how that response depends on other variables. We will assess the role of harvest and stocking in influencing walleye abundance and the entire fish community on a subset of lakes where suitable data are available. We will develop a prioritization scheme for managing fish communities under climate change and communicate results via data visualization and communication tools co-produced with fisheries management agencies. By generating lake-level predictions for multiple species in tens of thousands of lakes across multiple states, our results will be relevant for prioritizing climate adaptation management decisions at lake, watershed, county, state, and regional scales.

3.2.4 Determining the consequences of land management actions on primary drivers influencing smallmouth bass populations Tyler Wagner (PI)

Better understanding the drivers and stressors affecting fish health, fish habitat and aquatic conditions remains a significant management need in cool and warmwater rivers. Quantifying the effects of land management activities on aquatic ecosystems plays an important role in environmental management and decision-making. This research will address stakeholder needs related to understanding the effects of land management actions on stream and river habitat conditions – habitat that is critical for supporting socioeconomically and ecologically important

fish communities throughout the Chesapeake Bay Watershed. The project is a collaboration of researchers across multiple agencies and includes the USGS and state fisheries management agencies across the Chesapeake Bay Watershed. Through the development of several modeling frameworks, this research will focus on quantifying the effects of land management actions on population-level outcomes that are relevant to managers, including effects on abundance, recruitment, the number of spawners, and size structure.

3.2.5 Changes in stream fish distribution and occurrence in seven National Park Service units of the Eastern Rivers and Mountains Network Tyler Wagner (co-PI)

The National Park Service (NPS) mission to preserve, protect, and maintain the integrity of park ecosystems for the enjoyment of future generations relies upon access to science-based information regarding the status and trends of ecosystem condition. The Eastern Rivers and Mountains Network (ERMN) includes nine parks located in four states: New York, New Jersey, Pennsylvania, and West Virginia ranging in size from approximately 66 to 30,000 hectares with over 690 km of rivers and streams. The ERMN documents long-term change in the ecological integrity of one of the most abundant surface water ecosystems types in the network (high gradient, wadeable streams) by monitoring stream fish communities. Assessment of changes in fish community composition, occupancy and abundance is necessary in order to ensure the NPS mission is achieved. The project is a collaboration of researchers from USGS, NPS, and Pennsylvania State University. The statistical models developed during this project will inform decision making processes for the management of park ecosystems.

3.2.6 Diet composition of invasive flathead catfish in the Susquehanna River Basin: quantifying impacts on native and migratory fishes and recreational fisheries Tyler Wagner (co-PI)

Flathead Catfish are an indiscriminate predator of other fish and an expanding invader to large river systems outside of its native range, including the Susquehanna River Basin in Pennsylvania. Research efforts are beginning to provide insight on the distribution of this invader in the Susquehanna River Basin, however, there is considerable uncertainty about the potential ecological impacts of Flathead Catfish. In particular, there are concerns about their impacts on native and migratory fish species and on economically important recreational fisheries. To begin understanding the ecological effects of Flathead Catfish invasion, we propose a comprehensive diet study on Flathead Catfish in the Susquehanna River Basin. We will quantify Flathead Catfish diet composition using morphology and molecular identification of ingested prey items. Our study will help inform future fisheries management in the Susquehanna River Basin by increasing our understanding about the predatory effects and potential ecological consequences of invasive Flathead Catfish. The project is in collaboration with the Pennsylvania Fish and Boat Commission and Penn State University.

3.2.7 Quantifying the roles of changing watershed conditions and biotic interactions in structuring Pennsylvania stream fish communities Tyler Wagner (PI)

Understanding and predicting fish community interactions and their response to environmental stressors is of utmost importance for fisheries and water resource management. For example, state agencies and other water resource agencies rely on knowledge of stream and river fish communities for assessment programs, many of which have regulatory ramifications and implications for water and fisheries management and aquatic resource use activities. However, traditional fish community studies fail to accommodate potential interactions that exist among the entire fish assemblage and thus represent an overly simplistic view of community dynamics. This is important because treating species independently when quantifying and predicting their responses to changing watershed conditions ignores potential dependencies between species due to biotic interactions and can lead to erroneous predictions. Therefore, the overarching goal of this research is to help inform fisheries and water resource management and conservation by improving our understanding of the relative roles of fish species interactions, environmental factors, and how species traits influence a species' response to changing watershed conditions in Pennsylvania streams and rivers. The project is in collaboration with the Pennsylvania Fish and Boat Commission, the Pennsylvania Department of Environmental Protection, the Susquehanna River Basin Commission, and Penn State University.

3.2.8 Forecasting aquatic invasions in rivers: using riverscapes genetics to inform invasive fish species management at regional scales Tyler Wagner (PI)

To date, research on aquatic invasive species has focused primarily on predicting species occurrence using niche or habitat suitability models. While these models provide some indication of where in the basin an invasive species may already occur, they do not provide information about the dispersal potential through the river network, nor do they identify river or landscape (i.e., riverscape) characteristics that facilitate or restrict movement. This is a critical shortcoming, because migration through the river network is the primary means by which invasive species establish new populations. Understanding the factors that increase migration, rather than just occurrence, is important for developing regional invasive species management plans to prevent future range expansions. The goal of this study is to apply a novel quantitative framework for riverscape genetics recently developed by the PIs to better understand and predict the invasion potential of invasive fish species. The specific objectives are to (1) identify river and landscape covariates that increase dispersal and colonization rates of an invasive, apex fish predator, (2) predict the future range expansion of the invasive fish species to unsampled river reaches, (3) identify management scenarios that can be used to limit future invasion, and (4) develop a web viewer to communicate the efficacy of different management scenarios to end-users.

3.2.9 Quantifying the impacts of climate change on fish growth and production to enable sustainable management of diverse inland fisheries Tyler Wagner (co-PI), Gretchen Hansen

(PI, UM), Olaf Jensen (co-PI, University of Wisconsin-Madison), Jordan Read (co-PI, USGS Water Mission Area), Craig Paukert (co-PI USGS)

Fisheries managers in Midwestern lakes and reservoirs are tasked with balancing multiple management objectives related to the abundance and growth of several priority fish species across a landscape of diverse lakes. Growth rates of fish are indicators of population status, and directly influence the effectiveness of regulations designed to protect spawning fish or to promote trophy fishing opportunities. Growth, combined with reproduction and survival, also determines the amount of fish biomass available for harvest, known as population production. Changing water temperatures can influence growth and production of managed fish species in multiple and complex ways, increasing the opportunity for harvest in certain locations and decreasing it in others. In this project, we will quantify how climate change influences growth and productivity of priority fish species in lakes and reservoirs throughout the Midwest. This information will enable managers to adapt management objectives to take advantage of increased growth and harvest potential in certain places, while implementing protective actions where climate change is likely to have negative effects. Such work is particularly important given that climate change impacts on fish populations are often indirect, influencing species interactions, growth rates, and recruitment in ways that are often counterintuitive and vary across the landscape of Midwestern Lakes and reservoirs. This study builds upon previous advances in lake temperature modeling and ongoing work to estimate water temperature and its effects on managed fish abundance in upper Midwestern lakes by expanding the work to southern Midwestern reservoirs, and by partnering with fishery managers in Minnesota, Wisconsin, Iowa, and Missouri, and the Laurentian Great Lakes to link changes in lake temperatures to key management metrics related to fish size and harvest.

3.2.10* Scale, Space, and Time: A Unifying Approach to Aquatic Invasions Tyler Wagner (Senior personnel), Brandon Peoples (PI, Clemson), et al.

Species invasions are a major catalyst in the global biodiversity crisis, with particularly acute effects in river ecosystems. Yet despite decades of research, ecology still faces a glaring paradox: Many invasion theories are at odds with one another, but each is supported by strong empirical evidence. The paradox exists because studies have been constrained in three key dimensions: scale, space, and time. Using riverine fishes as a model system, the project team will integrate invasion theories to develop a more unified framework of species invasions. Because this research will be broadly applicable to other systems and taxa, it will support our partners, including state and federal fish and wildlife agencies, in their management decision making processes designed to prevent, manage, and predict the spread of invasive species.

3.3.1 The effects of targeted removal of deer groups on the epidemiology of chronic wasting

disease in wild white-tailed deer in Pennsylvania

Pennsylvania's CWD infection is currently in a relatively early stage of development. This provides some hope that an effective control strategy might protect the state's white-tailed deer resource. Potential elimination of CWD in free-ranging deer has occurred (e.g., New York) so it might be possible to focus targeted removal efforts on locations where CWD positive animals are found at or beyond the fringe of an infected area. We will implement a study designed to test and evaluate a systematic approach to controlling occurrence and distribution of CWD in Pennsylvania utilizing various harvest strategies (targeted removal of deer groups, altering hunting season) in areas CWD positive deer have been found. By employing a systematic program aimed at simultaneously trying to control the prevalence level within an area while attempting to eradicate new infections along the margin of the area, investigation of potential methods for effective control of CWD outbreaks is needed by state agencies or federal parks if CWD is discovered. This research will have management implications for various agencies by: (1) removing antler-point restrictions on harvest regulations of male deer, (2) controlled localized culling of deer to potentially reduce prevalence and transmission, and (3) a combination of 1 and 2 above as well as a control area with no management actions to assess the most suitable method to decrease prevalence and minimize/eliminate transmission out of the disease management area.

3.3.2 Epidemiology of West Nile virus in ruffed grouse Kristin Bondo, David Walter, Lisa Williams (PGC), Justin Brown (PGC)

Since its arrival in North America in 1999, West Nile virus (WNV) has had unprecedented adverse effects on the health of native bird species. In Pennsylvania, WNV was first documented statewide in 2002, soon after which population declines were observed in Pennsylvania ruffed grouse (*Bonasa umbellus*) and since then grouse populations have not recovered. Subsequent outbreaks of WNV are correlated with reductions in population indices of hunter flush rates and summer sighting survey (brood) data. In Spring 2015, the Unit assisted the Pennsylvania Game Commission by purchasing radiotransmitters to monitor wild grouse hens and collect eggs for a challenge study of naïve individuals inoculated with the WNV virus. Forty percent of chicks died within a week post-inoculation, and long term survival was questionable for an additional 30–50% of chicks. Recent research indicates there may be an interaction between habitat quality/quantity and the effect of WNV on grouse populations. More information is needed on the epidemiology of WNV with respect to ruffed grouse because nearly all research and monitoring has focused on WNV risk in human environments. Our objectives are to identify the mosquito species that coexist with ruffed grouse in early successional habitat, which mosquito species are important vectors of WNV for ruffed grouse, and which environmental factors increase the risk of WNV exposure to ruffed grouse. This information will result in background data to model the epidemiology of WNV across Pennsylvania to determine the ruffed grouse populations most at risk from the virus.

3.3.3 Phase II: Genetic assignment of white-tailed deer to population of origin. David Walter, Chris Rosenberry (PGC). Funding by the Pennsylvania Game Commission

Genetic assignment tests, using multi-locus genotypes, employ algorithms to cluster individuals together based on genetic similarity and can be used to identify migrants when individuals assign

to a population not representative of the genetic cluster they were sampled. These assignment methods can be useful for identifying the source of novel disease outbreaks particular for disease such as chronic wasting disease that can be sourced to captive or wild origins. Research on surveillance strategies, that consider demographic and environmental factors, is lacking in most states CWD has not been found. Developing surveillance strategies to maximize efficiency of sampling white-tailed deer has been recommended but requires knowledge of deer behavior, movements, and spatial connectivity of populations. Landscape genetics can provide the necessary framework to understand landscape features, dispersal characteristics of deer, and transmission and spread of CWD through assessment of population structure throughout a region. Phase I of this research identified 11 subpopulations with the Disease Management Areas (DMA) 1–3 in Pennsylvania and in Maryland/Virginia (see publications by Miller and others in Appendix C). Statewide assessment of subpopulation structuring would provide integral detail on potential for CWD spread throughout the state as well as a method of identifying new focal areas of the disease should they arise.

3.3.4 Optimizing CWD Surveillance: Regional Synthesis of Demographic, Spatial, and Transmission-Risk Factors. David Walter, Krysten Schuler (Cornell University), David Williams (Michigan State University), Sonja Christensen (Michigan State University), Aniruddha Belsare (Michigan State University), Dan Walsh (USGS), Chris Jennelle (Minnesota DNR), Brenda Hanley (Cornell University)

Chronic wasting disease (CWD) is a fatal disease of cervids with significant ecological and economic impacts. State wildlife agencies spend millions each year to test deer and elk for CWD, more so if they are one of 26 states that have previously detected the disease. Therefore, maximizing sampling efficiency and improving its effectiveness are critical. Several modeling efforts have already examined risk factors including sex, age, sample source, genetics, geophysical features, captive cervids, hunter-imported carcasses, and disposal methods to “sample smarter” and increase detection power; however, a rigorous integration of these various models has not happened. We will evaluate strengths and weaknesses of available analytical tools and determine which can be synthesized to derive a more powerful sampling strategy. The products of this synthesis will be a tool that integrates local harvest and disease prevalence data with data science, mathematical and statistical modeling techniques. This toolset will allow MI to more fully explore and optimize disease surveillance efforts. By identifying risk factors for CWD, states can tailor sampling protocols to maximize efficiency and confidence in disease prevalence. The strength of this project is to form a regional collaboration that will allow for standardization, comparison, and integration of CWD surveillance streams. All states involved will benefit from improved surveillance effectiveness, minimized cost of sampling, and maximize the probability of discovering new infections across state boundaries.

3.3.5 Parturition timing and calf survival in Pennsylvania elk. Avery Corondi (MS, PSU), David Walter, Jeremy Banfield (PGC), Justin Brown (PSU), Chris Roseberry (PGC). Funding by the Pennsylvania Game Commission

Recent evaluation of pregnancy rates in Pennsylvania elk (*Cervus elaphus*) suggest some level of delayed or asynchronous breeding. From 2013 to 2018, paired serum and uteri samples were collected from 245 adult females (ages 3-12) harvested during the general hunting season. These

samples were tested for pregnancy via a serum-based pregnancy specific protein B using an enzyme linked immunosorbent assay (PSPB) and gross examination, respectively. The PSPB was shown to be highly accurate at pregnancy detection in elk >15 days post conception (sensitivity: 95% and specificity: 91%) . In Pennsylvania, peak conception occurs from approximately 17 September to 9 September, with the general hunting season occurring around the first full week of November. Thus, pregnancy testing on harvested cows during the general hunting season captures at least one, and possibly two, estrus cycles. The average pregnancy rate during this period was 51.3% for adult aged females which prompted an additional blood collection during the late winters (January–April) of 2018 and 2019 with calculation of pregnancy rates again via PSPB. Late season pregnancy rates averaged 88.5% (Table 2), a notable increase from the early season average of 51.3%. The increase in pregnancy rates between autumn and late winter indicates asynchronous breeding, with a substantial proportion of reproductive aged females conceiving later than expected. Defining the calving season through use of vaginal implant transmitter (VIT) technology is a critical next step and will provide the data needed to calculate a more accurate estimate of the elk breeding season in Pennsylvania and determine what proportion of females are conceiving early or late in the breeding season. In addition, monitoring calf survival as a function of birth date will enable managers to evaluate the effect of asynchronous breeding/parturition on Pennsylvania's elk population. Intuitively, identifying factors that affect recruitment is a prerequisite for developing appropriate management responses.

3.3.6 *Minnesota white-tailed deer genetics within chronic wasting disease areas. Post Doc (Alberto Fameli), David Walter, Chris Jennelle (Minnesota DNR), Michelle Carstensen (Minnesota DNR). Funding by the United States Department of Agriculture through Minnesota Department of Natural Resources

It has been nearly four years since the Minnesota Department of Natural Resources (MNDNR) discovered CWD during the 2016 regular hunting season in Fillmore County, Minnesota. The disease has since expanded to central and north-central Minnesota suggesting that spatial spread of CWD continues to radiate from the core areas around Preston, MN and a previously positive captive cervid facility in Winona County. Minnesota's CWD infection appears to be in a relatively early stage of development. This provides hope that an effective control strategy might protect the state's white-tailed deer resource. Empirical evidence from 2019 and 2020 CWD management efforts suggests that targeted culling efforts were about 3 to 7 times more likely, respectively, to result in a CWD positive sample compared to regular hunter harvest efforts within the CWD Management Zone. Clearly, targeted culling of deer in close proximity to locations of CWD positive deer harvest provides Minnesota the most effective means to remove CWD positive deer from the landscape and mitigate deposition of infectious prions into the environment; however, we are uncertain if this tool is effective in minimizing disease spread through related individuals in close proximity to detected CWD positive deer. The objectives of this project are to conduct genetic analysis testing on up to 800 wild white-tailed deer muscle samples received from Minnesota during routine disease monitoring protocols. Assessing the relatedness among culled deer in close proximity to known CWD positive deer locations will permit us to establish if familial network structure exists in the pool of infected animals. This will provide a basis for evaluating whether particular social groups are high risk for CWD exposure and the effectiveness of our culling program.

3.3.7 *Establishing a national tissue and reagents repository for chronic wasting disease. Post Doc (TBD), David Walter, Stanton Martin (Oak Ridge National Laboratory), Jason Bartz (Creighton University). Funding by the U.S. Geological Survey

The prevalence of CWD within cervid populations can approach 50% and, since CWD is always fatal, CWD can have detrimental effects on cervid populations (Edmunds et al. 2016, DeVivo et al. 2017). CWD belongs to a group of diseases that are caused by prions, infectious proteins that can infect new species (e.g. transmission of mad cow disease to humans). Monitoring, characterizing, and tracking progression of CWD across the US has not been possible because identification of distinct strains of CWD has been lacking. Prion strains can differ considerably in their ability to cause disease in cervids and the potential to infect a new species. Although this understanding of the biology of prions has been well studied, prion researchers have been unable to study prion strains because in multiple regions of the US because of the lack of availability of samples positive for CWD. Unfortunately, a centralized collection of CWD tissues is not currently available. The overall goal of this program is to establish a virtual CWD tissue and reagents repository. The significance of this program is multifold. First, a repository of CWD field isolates from a wide-ranging geographic location in North America will allow, for the first time, the means to begin to assess the distribution and frequency of CWD strains in North America. Since prion strains can differ in pathogenicity and host range, this is essential data for the determination for risk of interspecies prion transmission to humans and to domestic livestock and wildlife. Second, this repository can provide uniform standardized CWD-infected and uninfected sources of tissue for diagnostic development, mitigation testing and for basic research purposes. Finally, the implementation of the repository will facilitate cooperation between the various state agencies that could lead to new collaborative efforts.

3.3.8 *Assessment of movement of prions across the captive-wild interface. Post Doc (TBD), David Walter, Kurt VerCauteren (United States Department of Agriculture), Deep Tewari (Pennsylvania Department of Agriculture). Funding by the National Wildlife Research Center, USDA-APHIS-WS.

Pennsylvania has detected chronic wasting disease (CWD) in captive and wild white-tailed deer since 2012. Since first detection occurred in the same year in both captive and wild deer, it is difficult to ascertain the role the captive-wild interface has on disease transmission in the state. Since 2012, over 10 captive cervid facilities and 250 wild deer have tested positive for CWD. Considering Pennsylvania is second only to Texas in the number of captive facilities statewide, assessment of various components of the captive-wild interface are warranted. Previous studies have documented crows were able to transmit infectious prions responsible for CWD in a controlled laboratory setting but field evaluation of this possibility has yet to be tested. Furthermore, limited information exists as to wildlife species' use of captive facilities or areas surrounding these facilities to evaluate the role these species play, if any, of movement of prions around the landscape. Our primary objective is to determine potential exchange of infectious prion protein material between captive cervid facilities and surrounding areas using Real-Time Quaking-Induced Conversion (RT-QuIC) assays. Our secondary objective is to monitor use of captive cervid facilities by crows and track their movements on and off captive-cervid facilities.

Frequency of use of facilities and movements off facilities can provide an index of risk of prion spread even if prions are not detected using RT-QuIC.

Appendix C – Awards, Publications, and Presentations (Unit personnel and students in bold)

Honors and Awards

Danielle Massie selected as a recipient for the Distinguished Master's Thesis Award.

Duane Diefenbach was awarded the John Pearce Memorial Award by the Northeast Section of The Wildlife Society. The award recognizes Society members in the Northeast for outstanding professional accomplishments in wildlife conservation in the Northeast.

Peer-reviewed Publications

Diefenbach

Murphy, A. M., D. R. Diefenbach, M. Ternent, M. Lovallo, D. Miller. 2021. Threading the needle: How humans influence predator-prey spatiotemporal interactions in a multiple-predator system. *Journal of Animal Ecology* <https://doi.org/10.1111/1365-2656.13548>

Diefenbach, D. R., W. M. Knox, and C. S. Rosenberry. 2021. The Future of Managing Ungulate Species: White-tailed Deer as a Case Study. Pages 327-340 in K. Pope and L. Powell, editors. *Harvest of fish and wildlife: new paradigms for sustainable management*. CRC Press, Boca Raton, Florida, USA

Miller-Butterworth, C. M., **D. R. Diefenbach**, J. E. Edson, L. A. Hansen, J. D. Jordan, **T. M. Gingery**, and A. L. Russell. 2021. Demography and loss of genetic diversity in two insular populations of the bobcat (*Lynx rufus*). *Global Ecology and Conservation*. 26:e01457 <https://doi.org/10.1016/j.gecco.2021.e01457>

Van Buskirk, A., C. S. Rosenberry, B. D. Wallingford, E. J. Domoto, M. E. McDill, P. Drohan, and **D. R. Diefenbach**. 2021. Modeling how to achieve localized areas of reduced white-tailed deer density. *Ecological Modelling* 442:109393 <https://doi.org/10.1016/j.ecolmodel.2020.109393>

Long, E. S., D. R. Diefenbach, C. L. Lutz, C. S. Rosenberry, **B. D. Wallingford**. 2021. Risky movements? Natal dispersal does not decrease survival of white-tailed deer. *Ecology and Evolution*. DOI: 10.1002/ece3.7227.

Gingery, T. M., D. R. Diefenbach, C. E. Pritchard, D. C. Ensminger, B. D. Wallingford, and C. S. Rosenberry. 2020. Survival is negatively associated with glucocorticoids in a wild ungulate neonate. *Integrative Zoology* 16:214-225. <https://doi.org/10.1111/1749-4877.12499>

Michel, E. S., B. K. Strickland, S. Demarais, J. L. Belant, T. M. Kautz, J. F. Duquette, D. E. Byer, Jr., M. J. Chamberlain, K. V. Miller, R. M. Shuman, J. C. Kilgo, **D. R. Diefenbach**, B. D. Wallingford, J. K. Vreeland, S. S. Ditchkoff, C. S. DePerno, C. E. Moorman, M. C.

Chitwood, and M. A. Lashley. 2020. Relative reproductive phenology and synchrony affect neonate survival in a nonprecocial ungulate. *Functional Ecology* 34:2536–2547. <https://doi.org/10.1111/1365-2435.13680>

Wagner

Liang, Z., Y. Liu, Y. Xu, T. Wagner. 2021. Bayesian change point quantile regression approach to enhance the understanding of shifting phytoplankton-dimethylsulfide relationships in aquatic ecosystems. *Water Research*.

Smith, G.D., D.L. Massie, J. Perillo, T. Wagner, D. Pierce. Accepted. Range expansion and factors affecting abundance of invasive Flathead Catfish at the Delaware and Susquehanna rivers, Pennsylvania, USA. *North American Journal of Fisheries Management*.

Smalling, K.L., O.H. Devereux, S.E. Gordon, P. Phillips, V.S. Blazer, M.L. Hladik, D.W. Kolpin, M.T. Meyer, A.J. Sperry, and T. Wagner. 2021. Environmental and anthropogenic drivers of contaminants in agricultural watersheds with implications for land management. *Science of the Total Environment* 145687.

Massie, D.L., G.J.A. Hansen, Y. Li, G.G. Sass., and T. Wagner. Accepted. Do lake-specific characteristics mediate the temporal relationship between walleye growth and warming water temperatures? *Canadian Journal of Fisheries and Aquatic Sciences*.

Gatch, A. Z. Biesinger, E. Bruestly, C. Karboski, K. Lee, T. Wagner, M. Bartron, D. Gorsky. 2021. Discovery of Successful River Spawning by Lake Trout (*Salvelinus namaycush*) in the Lower Niagara River, Lake Ontario. *Journal of Great Lakes Research*.

Liang, Z., Y. Xu, Q. Qiu, Y. Liu, W. Lu, and T. Wagner. 2021. Developing Joint Nutrient Criteria Using Quantile Regression for Lake Eutrophication Management. *Journal of Hydrology* 594:125883.

Lapierre, J-F., S.M. Collins, S.K. Oliver, E.H. Stanley, T. Wagner. 2021. Inconsistent browning of Northeastern US lakes despite increased precipitation and recovery from acidification. *Ecosphere* 12 e03415.

Massie, D.L., Y. Li, and T. Wagner. A framework for detecting macroscale drivers on fish growth. 2020. *Canadian Journal of Fisheries and Aquatic Sciences* 78.

Thompson, T.J., M.A. Briggs, P.J. Phillips, V.S. Blazer, K.L. Smalling, D.W. Kolpin, T. Wagner. 2020. Groundwater discharges as a source of phytoestrogens and other agriculturally derived contaminants to streams. *Science of the Total Environment*.

Li, Y., V.S. Blazer, L.R. Iwanowicz, M.K. Schall, K. Smalling, D. Tillitt, and T. Wagner. 2020. Ecological risk assessment of environmental stress and bioactive chemicals to riverine fish populations: an individual-based model of smallmouth bass *Micropterus dolomieu*. *Ecological Modelling* 438:109322.

- White, S.L. and T. Wagner. 2021. Behavior at short temporal scales drives dispersal dynamics and survival in a metapopulation of brook trout (*Salvelinus fontinalis*). *Freshwater Biology* 66:278–285.
- Liang, Z., P.A. Soranno, T. Wagner. 2020. The role of phosphorus and nitrogen on chlorophyll a: evidence from hundreds of lakes. *Water Research* 185:116236.
- Maynard-Bean, E. E. M. Kaye, T. Wagner, E.P. Burkhart. 2020. Citizen scientists record novel leaf phenology of invasive shrubs in eastern U.S. forests. *Biological Invasions* 22:3325–3337.
- Wagner, T., G.J.A. Hansen, E. Schliep, B. Bethke, A. Honsey, P. Jacobson, B.C. Kline, and S.L. White. 2020. Improved understanding and prediction of freshwater fish communities through the use of joint species distribution models. *Canadian Journal of Fisheries and Aquatic Sciences* 77:1540-1551.
- Schall, M.K., G.D. Smith, V.S. Blazer, H.L. Walsh, Y. Li, and T. Wagner. 2020. A fishery after the decline: The Susquehanna River Smallmouth Bass story. *Fisheries* 45:576-584.

Walter

- Edson, J., J. Brown, W.M. Miller, **W.D. Walter**. Comparison of sample types from white-tailed deer (*Odocoileus virginianus*) for DNA extraction and analyses. *Scientific Reports* **11**, 10003. <https://doi.org/10.1038/s41598-021-89390-2>
- Ganoe, L.S., M.J. Lovallo, J.D. Brown, and **W.D. Walter**. Ecology of an isolated muskrat population during regional population declines. *Northeastern Naturalist* 28(1):49–64.

Presentations at Scientific Meetings

Diefenbach

- Van Buskirk, A., C. S. Rosenberry, B. D. Wallingford, E. J. Domoto, M. E. McDill, P. Drohan, D. R. Diefenbach.** 2021. Modeling how to achieve localized areas of reduced deer density. Southeast Deer Study Group Meeting, 9 October 2020.
- Buderman, F. E., **T. M. Gingery, D. R. Diefenbach, L. C. Gigliotti, D. Begley-Miller, B. D. Wallingford, C. S. Rosenberry.** Using animal space-use and movement to infer behavioral states: A cautionary tale. Southeast Deer Study Group Meeting, 23 February 2021.
- Gingery, T. M. and D. R. Diefenbach.** 2021. Fawn survival patterns: looking beyond predators. Southeast Deer Study Group Meeting, 23 February 2021.
- Van Buskirk, A., C. S. Rosenberry, B. D. Wallingford, E. J. Domoto, M. E. McDill, P. Drohan, D. R. Diefenbach.** 2021. Modeling how to achieve localized areas of reduced deer density. Southeast Deer Study Group Meeting, 23 February 2021.
- Diefenbach, D. R., M. J. Casalena, P. L. Fackler.** A Decision Model for Setting Fall Harvest Regulations for Wild Turkey. Annual Conference of the Northeast Association of Fish and Wildlife Agencies. Virtual conference, 26-28 April 2021.

- Bayuzick, S., P. Drohan, T. Raab, F. Hirsch, A. Bonhage, M. McDill, and **D. Diefenbach**. Relic charcoal hearths geomorphology and hydrology in mid-Appalachian region of Pennsylvania. Virtual EGU General Assembly 2021, 19 April 2021.
- Drohan, P., S. Bayuzal, **D. Diefenbach**, M. McDill, T. Raab, F. Hirsch, and A. Bonhage. Northern Appalachian, USA relic charcoal hearths and their unique Ecological Fingerprint. Virtual EGU General Assembly 2021, 19-30 April 2021.
- Buderman, F. E., **T. M. Gingery, D. R. Diefenbach, L. C. Gigliotti, D. Begley-Miller**, M. E. McDill, B. D. Wallingford, C. S. Rosenberry, and P. D. Drohan. Guidance on inferring behavioral states from animal location data. 31 May - 11 June, 2021, EURING Technical Meeting, Quebec City, Quebec, Canada.
- Gunderman, K. P., **D. R. Diefenbach, W. D. Walter**, and F. E. Buderman. Efficacy of positional and behavioral change-point models to determine ungulate parturition events. 31 May - 11 June 2021, EURING Technical Meeting, Quebec City, Quebec, Canada.

Wagner

- Schall, M.K., G.D. Smith, J.D. Avery, and T. Wagner. 2021. Comparing the use of multiple molecular techniques for identification of prey items in invasive Flathead Catfish (*Pylodictis olivaris*) diets. Southern Division of the American Fisheries Society.
- Stark, S.K., M.K. Schall, G.D. Smith, J.D. Avery, and T. Wagner. 2021. Let's eat! A look at the diet of the invasive Flathead Catfish (*Pylodictis olivaris*) in the Susquehanna River Basin, PA. Southern Division of the American Fisheries Society.
- Stark, S.K., M.K. Schall, J.D. Avery, G.D. Smith, and T. Wagner. 2021. Evaluating sampling techniques of Flathead Catfish, *Pylodictis olivaris*, in the Susquehanna River Basin for dietary analysis. Pennsylvania Chapter of the American Fisheries Society Spring Technical Meeting. February 11-12, 2021.
- Hansen, G., B. Bethke, J. Dumke, J. Hirsch, K. Kovalenko, J. leDuc, R. Maki, H. Rantala, and T. Wagner. 2021. Impacts of invasive spiny water fleas and zebra mussels on first-year growth of walleye and yellow perch in Minnesota's large lakes. Rainy-Lake of the Woods Watershed 2021 Forum. March 10-11, 2021.
- Krause, K., K. Maloney, T. Wagner. 2020. Analyzing stream fish communities of the Chesapeake Bay watershed: A joint species distribution modeling approach. Annual Meeting of the American Fisheries Society.

Walter

- Gunderman, K. P., **D. R. Diefenbach, W. D. Walter**, and F. E. Buderman. Efficacy of positional and behavioral change-point models to determine ungulate parturition events. 31 May - 11 June 2021, EURING Technical Meeting, Quebec City, Quebec, Canada.