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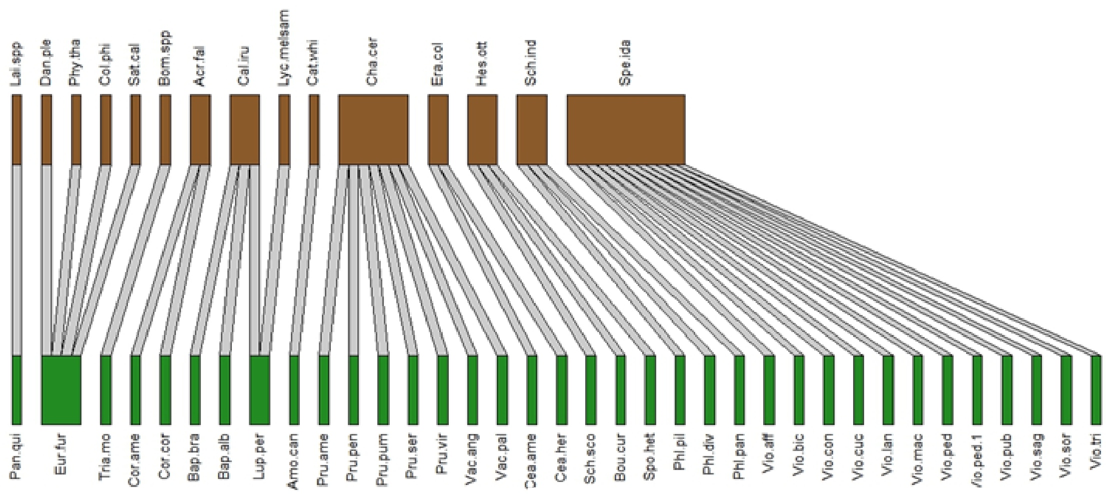
Center for the Advancement of Sustainability Innovations (CASI)

Identification of Insect-Plant Pollination Networks for a Midwest Installation

Fort McCoy, WI

Irene E. MacAllister, Jinelle H. Sperry, and Pamela Bailey

April 2016



Results of an insect pollinators bipartite mutualistic network analysis.

CASI
Center for the Advancement of Sustainability Innovations

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Identification of Insect-Plant Pollination Networks for a Midwest Installation

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Abstract

Pollinating insects and pollinator dependent plants are critical components of functioning ecosystems yet, for many U.S. Department of Defense (DoD) installations, the identities and relationships between pollinators and plants are unknown. This study demonstrated methods for compiling and analyzing readily available information for insect pollinators and pollination dependent plants for a single installation, Fort McCoy, WI. Although installation documents identified a total of 1470 insect species and 972 plant species were identified on the installation, this work focused on species of conservation concern (nine pollinator insect species and three pollinator-associated plant species). Published information on insect pollinators and pollination dependent plants was then used to conduct a basic plant-pollinator network analyses using free analytical network software (software package R), which revealed that all the plant species of conservation concern are pollinated by several insect pollinator species. However, many pollinator insect species of conservation concern were associated with a limited number of host plant species. The results of this work suggest that analyses that rely on publicly available information provide a useful starting point in determining basic, binary plant-pollinator relationships. Field-collected data, e.g., frequency of pollinator-plant interactions, would be required for a more detailed, robust network analysis.

Executive Summary

Pollinating insects and pollinator dependent plants are critical components of functioning ecosystems. As such, recent emphasis has been placed on a greater understanding and conservation of plant-pollinator networks. Regulations aimed at maintaining and restoring healthy plant-pollinator communities are being developed and implemented at both the federal and state levels that will impact U.S. Department of Defense (DoD) land management.

This study provides a template for assessing plant-pollinator networks on DoD lands that can help achieve pollinator management objectives. Fort McCoy, WI was used as an example installation to provide guidance on how to acquire data on plant and pollinator distribution, ecology and network traits. This method can be used by installations to assess the plant-pollinator communities on their lands and their vulnerability to declining pollinator populations. This exercise also provides guidance on how to construct plant-pollinator databases and conduct basic network analyses. The results of the basic network analyses can reveal critical knowledge gaps which could identify the need for field collected data.

Contents

Preface

This study was performed under the Center for the Advancement of Sustainability Innovations (CASI). CASI was established by the U.S. Army Engineer Research and Development Center (ERDC) as a new capability in 2006, hosted at the Construction Engineering Research Laboratory (CERL) in Champaign, IL. CASI's mission is to focus ERDC expertise, technologies and partnerships toward helping the U.S. Army Corps of Engineers (USACE), the Army, and the Department of Defense (DoD) achieve more sustainable missions, facilities, and operations. The technical monitor and Associate Director of CASI was Franklin H. Holcomb.

The work was performed by the Environmental Processes Branch (CN-E) and the Ecological Processes Branch (CN-N) of the Installation Division (CN), Construction Engineering Research Laboratory (CERL) Champaign IL and the Environmental Laboratory (EL), Vicksburg, MS. The authors would like to thank Jacob Dixon, Taylor West and Jason Gleditsch for assistance with data acquisition and analyses. At the time of publication, H. Garth Anderson was Acting Chief, CEERD-CN-E; William D. Meyer was Chief, CEERD-CN-N; and Michelle Hanson was Chief (CEERD-CN). The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director was Dr. Ilker Adiguzel.

CERL and EL are elements of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Bryan S. Green, and the Director of ERDC is Dr. Jeffery P. Holland

1 Introduction

1.1 Background

Pollinators and pollinator dependent plants are critical components of functioning ecosystems (Cane and Tepedino 2001). Nearly 88% of extant flowering plant species are dependent on animal pollinators, including many agricultural plants (Ollerton et al. 2011). The recent declines of pollinator species, particularly bees, have received global attention (Biesmeijer et al. 2006, Potts et al. 2010) and the dire consequences of these declines have been well documented in the scientific literature (Meffe 1998; Kevan and Phillips 2001). While the attention has led to a proliferation of research on the topic, much is still unknown. For many systems, basic information, such as the identities and relationships of plants and pollinators, has not been explored.

For the U.S. Department of Defense (DoD) and the Army, information on plant-pollinator interactions can be critical for a number of reasons. Numerous federally listed threatened/endangered species are dependent on plant-pollinator interactions, either because the listed species is a pollinator species or is dependent on one. Currently, approximately 75% of 296 species at risk (SAR) flowering plants on installations are pollinator dependent (NatureServe 2011). Thus, the number of federally listed threatened/endangered species is likely to grow. Federally listed species on military lands can incur substantial costs to the military, both in terms of management costs, and more importantly, in the costs associated with reduced ability to train (DoD 2014, Lachman 2013). Further, the Army has an obligation to maintain range lands so that troops can “train as they fight.”

The importance of pollinators in their role for ecosystem service, and the concern over their recent declines, has led to a variety of initiatives aimed at pollinator conservation on military lands (Anderson and Bailey 2010). Regulations and/or guidance has been issued across multiple levels of government including Presidential and DoD memoranda (White House 2014, USD[AT&L] 2014). These regulations require land managers to conduct land management that is considered “pollinator-friendly.” However, for installations in which plant-pollinator relationships have not yet been identified, this can pose a daunting task. Readily available resources are available from a large number of government, academic, and non-governmental organization (NGO) sources, but that information is widespread and difficult to synthesize. This work was undertaken to demonstrate methods to compile and analyze publicly available plant-pollinator information for a single installation, Fort McCoy, WI, and to provide guidance on how to locate valid sources of information, compile species and region-specific data, and conduct basic plant-pollinator network analyses. This Midwestern installation was selected because:

1. The Midwest represent a knowledge gap for DoD programs as few past studies have focused on the Midwest (http://www.dodpollinators.org/DoD-Projects.html).
2. The Midwest is significant as it is a flight corridor for the Monarch Butterfly.
3. Fort McCoy is habitat for the federally listed endangered Karner Blue Butterfly (KBB).
4. The available information for Fort McCoy for insects and pollinator-dependent plants is extensive and covered in their Integrated Natural Resource Management Plans (Forster et al. 2012).

1.2 Recent Drivers

Several recent pollinator specific decision-making guidance documents have been issued:

The White House. 20 June 2014. Presidential Memorandum — Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators. SUBJECT: Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators. Washington, DC: The White House, Office of the Press Secretary, https://www.whitehouse.gov/the-press-office/2014/06/20/presidential-memorandum-creating-federal-strategy-promote-health-honey-b

Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (USD[AT&L]). 05 September 2014. Memorandum for Assistant Secretary of the Army (Installations, Energy and Environment) Assistant Secretary of the Navy (Energy, Installations and Environment) Assistant Secretary of the Air Force (Installations, Environment and Logistics) Staff Director, Defense Logistics Agency (DSS-E). SUBJECT: Department of Defense (DoD) Policy to Use Pollinator-Friendly Management Prescriptions. Washington, DC: USD(AT&L), http://www.dodpollinators.org/Pollinator_Friendly_Management_-_signed_memo001.pdf

The White House. 19 May 2015. *The Department of Defense's Role in the National Strategy to Promote the Health of Honey Bees and Other Pollinators*. Washington, DC: The White House, Pollinator Health Task Force, http://www.dodpollinators.org/Pollinator_Health_Strategy_2015_for_DoD.pdf

1.3 Study Objectives

The overall objectives of this study were to: (1) identify and compile information on pollinating insect fauna and pollinator dependent flowering plants for Fort McCoy, WI, (2) identify which of the species are considered species-at-risk (based on NatureServe Global Conservation Ranking [www.natureserve.org]), and (3) demonstrate methods for basic plant-pollinator network analyses for those at-risk species.

1.4 Scope

Although the scope of this research was limited to Fort McCoy, WI, it is anticipated that the results of this work will be broadly applicable to other DoD installations.

1.5 Approach

The study was conducted using currently available sources including scientific (and gray) literature, web-based information (including electronic databases), and field guides. A database was constructed that included occurrence data for insect pollinators, flowering plants, and likely interactions/dependencies between the two. Basic network analyses were conducted to evaluate number and strength of relationships between insect pollinators and dependent flowering plants for imperiled species. The following tasks were completed:

1. Created a database of Fort McCoy pollinator insect fauna.
2. Created a database of Fort McCoy flowering plants.
3. Identified at-risk (G1-G3) pollinating insect fauna on Fort McCoy.
4. Identified at-risk (G1-G3) flowering plants on Fort McCoy.
5. Performed a basic network analysis on G1-G3 pollinating insects and flowering plants.

2 Methods

To determine the species that would be included in the network analyses, a database was created of all insect and plant species present on our focal installation, Fort McCoy, WI. In this case, the Fort McCoy Integrated Natural Resource Management Plan (Forster et al. 2012) provided compiled lists of all species found on the installation. Native bees likely to occur on Fort McCoy were also added to the database of insect pollinator fauna because these species were absent from the Fort McCoy Integrated Natural Resources Management Plan. For general application of these methods, county level species occurrence data is available from a variety of sources (e.g., http://explorer.natureserve.org).

Because installations give highest priority to at-risk species, this work focused only on plant/pollinator species of conservation concern. NatureServe Global Conservation Status Ranks were used to classify species according to their vulnerability to extinction. Only species with Global Ranks of G1 (critically imperiled), G2 (imperiled), or G3 (vulnerable) were included in the network analyses.* Species that were not assigned ranks by NatureServe (e.g., hybrids) were not included in analyses. The reproductive mode of species identified as at-risk was then determined. Insect species that are not pollinators and plant species that are not pollinator dependent were excluded.

For the reduced list of species, likely plant-pollinator pairs were identified based on an extensive literature review. For plants, in order of specificity, each species was classified by its pollinator syndrome category,† general pollinators (e.g., bees), specific pollinator species, and then pollinator species present on Fort McCoy. Similarly, for pollinators, each species was classified by its pollinator syndrome category, general plant associations (e.g., legumes), specific plant species association, and the associated plant species on Fort McCoy.

Network analyses are a common tool used to examine relationships and connectedness in plant-pollinator systems. A large body of literature is

* For more information on Global Conservation Status Ranks, see NatureServe (2015), http://explorer.natureserve.org/granks.htm

† Pollinator Partnership (2006), http://www.pollinator.org/Resources/Pollinator_Syndromes.pdf

available on many aspects of plant-pollinator networks including geographic variation of networks (Olesen and Jordano 2002), influences of climate change (Memmott et al. 2007, Heglan et al. 2009), effects of invasive species (Lopezaraiza-Mikel et al. 2007; Bartomeus, Vilà, and Santamaría 2008) and temporal variation in network properties (Basilio et al. 2006; Alarcón, Waser, and Ollerton 2008). Binary networks, in which identities of plant-pollinator pairs are identified, allow basic analyses of connectance (e.g., number of links). Quantitative networks, those that incorporate frequencies of interaction, allow more refined analyses of specialization (Blűthgen, Menzel, and Blűthegen 2006). A detailed quantitative network would require extensive data collection on interaction frequencies and sampling intensity, an effort that is beyond the scope of this project. This work presents a very simple binary network to demonstrate how network analyses can be used for plant-pollinator management. The “bipartite” package library in *Program R* (Dormann, Gruber, and J. Fründ. 2008; Dormann et al. 2009) was used to analyze the Fort McCoy plant-pollinator network. Appendix B to this report includes annotated code; Appendix C provides an example of how to format data for the analyses.

3 Results

The Fort McCoy Integrated Natural Resource Management Plan (Forster et al. 2012) identified 1470 insect species and 972 plant species that are found on the installation. Of those, nine pollinator species were considered at-risk (all with global ranking of G3) and three pollinator-associated plant species were considered at-risk (G1 - G3; Table 3-1).

All of the identified plant species of conservation concern are pollinated by numerous pollinator species that are found on Fort McCoy. Known pollinator of *Panax quinquefolius* (American Ginseng) are halictid sweat bees and syrphid hover-flies (Duke 1980), both of which have representatives on McCoy. Known pollinators of *Trifolium amoenum* (Showy Indian Clover) include bumblebees (*Bombus spp*.) (Knapp and Connors 1999) and *Eurybia furcata/Aster furcatus* (Forked Aster) is pollinated by a wide variety of pollinator groups (Hilty 2015), many with numerous species present on Fort McCoy (Table 3-1).

Many of the pollinator species of conservation concern are associated with a limited number of host plant species. Nearly all of the pollinator species of conservation concern on Fort McCoy were associated with a single genus or species of host plant. In particular, the Karner Blue Butterfly, a federally endangered species, is dependent on Lupine, of which only one species, *Lupinus perennis*, is present on Fort McCoy (Figure 3-1).

Table 3-1. Species of concern and the relevant pollination interaction.

Scientific Name	Common Name	Global Rank	Pollinators
PLANTS			
Panax quinquefolius	American Ginseng	G3 - Vulnerable	Wild Bees, Syrphid Flies
Eurybia furcata/Aster furcatus	Forked Aster	G3 - Vulnerable	Bees, Syrphid Flies, Butterflies
Trifolium amoenum	Showy Indian Clover	G1 – Critically Imperiled	Bumble Bees
INSECT POLLINATORS			*HOST PLANT*
Acronicta falcula	Corylus Dagger Moth	G3 - Vulnerable	Corylus
Callophrys irus	Frosted Elfin	G3 - Vulnerable	Wild Indigo & Lupine
Catocala whitneyi	Whitney's Underwing	G3 - Vulnerable	Lead Plant
Chaetaglaea cerata	Noctuid Moth	G3 - Vulnerable	Prunus spp. and Blueberry spp.
Erastria coloraria	Broad-lined Erastra	G3 - Vulnerable	Ceanothus spp.
Hesperia ottoe	Ottoe Skipper	G3 - Vulnerable	Prairie grasses
Schinia indiana	Phlox Moth	G3 - Vulnerable	Phlox spp.
Lycaeides melissa samuelis	Karner Blue Butterfly	Federal Endangered	Lupine
Speyeria idalia	Regal Fritillary Butterfly	G3 - Vulnerable	Viola spp.

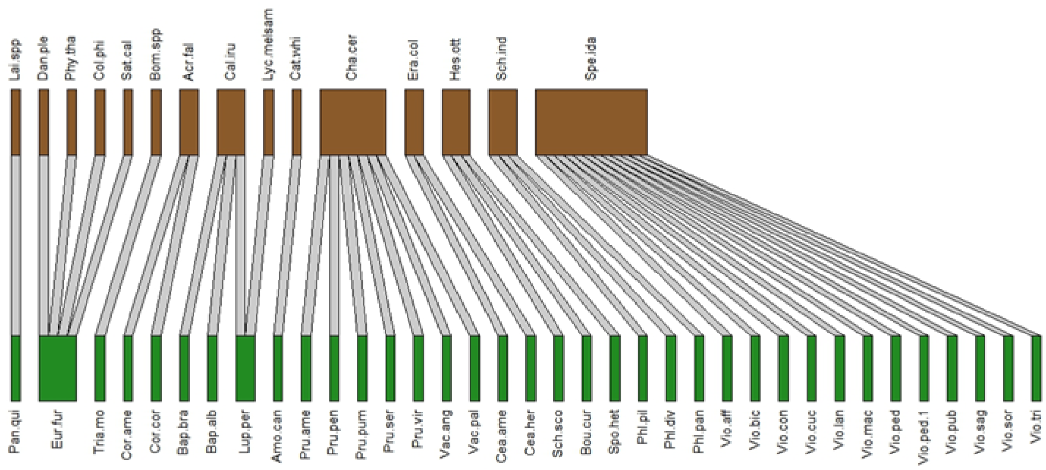

Figure 3-1. Results of the insect pollinators bipartite mutualistic network analysis. Pollinators are indicated with brown boxes and plants species are in green.

4 Discussion

The identification of plant-pollinator interactions is a key step in the conservation of species dependent on this mutualistic relationship. In depth examinations of plant-pollinator relationships can yield important insights into many aspects of these interactions. Furthermore, an understanding of plant-pollinator relationship at the community level rather than at the individual species level is pertinent as most pollinators and pollinator dependent plants are generalists. Pollination network analysis is one method that enables the examination of plant-pollinator interactions at the community level. A simple pollination network can be created via a binary network in which both pollinators and plants are nodes and the plant-pollinator interactions form the links between the nodes. Although far from comprehensive, an extensive amount of data is readily available on the distribution of plants and pollinators and their potential relationships.

While the information gathered from publically available sources is useful, it may be incomplete. Detailed information on interaction patterns between pollinators and plants is available for only a limited number of species, likely because it can be very time intensive and costly to identify these interactions. This work compiled readily available information to construct a database of plant-pollinator species and relationships at Fort McCoy, WI, and created binary plant-pollinator networks using that information. The objective here was to demonstrate how and where to find data on plants and pollinators, and to provide a framework for analyzing plant-pollinator networks to, ultimately, help manage these plant-pollinator communities.

This effort used published plant and insect species lists for Fort McCoy that were identified in the installation’s Integrated Natural Resource Management Plan. For installations/regions where species lists have not already been compiled, county level species occurrence data is available from a variety of sources (Appendix A). However, even with the detailed species lists available for Fort McCoy, only general pollinator information (e.g., bees) was available for the majority of plants species. Although many of these species are likely pollinated by a wide suite of pollinator species, more detailed information on the frequency of interactions among species would be valuable. For example, more detailed research such as field collected data documenting plant visitation by pollinators, analysis of pollen loads present on insects or use of insect traps, would strengthen the conclusions drawn from a network analysis.

Nearly all of the pollinator species of conservation concern on Fort McCoy were dependent on a single genus or species of host plant. This specificity of host plant requirement is likely a contributing factor behind the population declines for co-evolved species. On Fort McCoy, two of the pollinator species of concern, the Frosted Elfin Butterfly and Karner Blue Butterfly, are dependent on Lupine species, highlighting the important role that Lupine plays in plant-pollinator networks on this site. As part of their strategy for Karner Blue conservation, Fort McCoy has engaged in numerous management actions aimed at increasing the Lupine population on the installation (Forster et al. 2012). This proactive management of both pollinators and their associated host plants provides an effective example of the types of management strategies that can be accomplished when detailed information is available on plant-pollinator relationships.

Although this work conducted its network demonstration using *Program R*, many statistical programs are available for similar analyses. The bipartite package in *Program R* was found to be user friendly and easily adaptable to the dataset and questions of interest. Although the data available were only sufficient for a simple binary network analysis, additional packages in *Program R* allow for more complex network analyses if more detailed data were available. Appendix B to this report includes sample (annotated) *Program R* code; Appendix C provides a dataset for ease of replication.

There are more than 20 threatened and endangered species of pollinators on military installations (ref. DoDPollinators.org). In addition, there are 222 SAR angiosperms on military installations, many of which are dependent on pollination services. The identification of pollinator-angiosperm interactions is essential to the preservation of the overall ecosystem health and biodiversity. This study provided information specific to pollination ecology for Fort McCoy in terms of plant/pollinator association. However, the information and methods described here have DoD-wide significance in that they may potentially prevent further pollinator and flowering plant declines on other installations.

Follow-on work to this study could entail the documentation to support stewardship obligations of insect pollinator-plant networks for other Mid-western installations, for installations in the Northeast and Northwest, and for locations in sensitive ecosystems predisposed to climatic pressures such as the Arctic or the Pacific Islands. Furthermore, information for plant/pollinator associations may be used as a starting point for more in-depth field studies for Fort McCoy and the surrounding area. Actual field studies such as native bee surveys and actual plant visitation rate studies may be necessary to establish plant-pollinator networks. This information, when collated and synthesized, can be used to inform management and identify important knowledge gaps.

Acronyms and Abbreviations

Term	Definition
AERTA	Army Environmental Requirements and Technology Assessments
BMC	BioMed Central (Ltd.)
CASI	Center for the Advancement of Sustainability Innovations
CEERD	US Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
DoD	U.S. Department of Defense
EL	Environmental Laboratory
ERDC	U.S. Army Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
INRMP	Integrated Natural Resources Management Plans
KBB	Karner Blue Butterfly
NAPPC	North American Pollinator Protection Campaign
NGO	Nongovernmental Organization
SAR	Species at Risk
SF	Standard Form
SR	Special Report
TER-S	Threatened, Endangered, and At-Risk Species
U.S.	United States
USDA	U.S. Department of Agriculture

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Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (USD[AT&L]) 05 September 2014. Memorandum for Assistant Secretary of the Army (Installations, Energy and Environment) Assistant Secretary of the Navy (Energy, Installations and Environment) Assistant Secretary of the Air Force (Installations, Environment and Logistics) Staff Director, Defense Logistics Agency (DSS-E). SUBJECT: Department of Defense (DoD) Policy to Use Pollinator-Friendly Management Prescriptions. Washington, DC: USD(AT&L), http://www.dodpollinators.org/Pollinator_Friendly_Management_-_signed_memo001.pdf

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White House, The. 20 June 2014. *Presidential Memorandum — Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators. SUBJECT: Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators*. Washington, DC: The White House, Office of the Press Secretary, https://www.whitehouse.gov/the-press-office/2014/06/20/presidential-memorandum-creating-federal-strategy-promote-health-honey-b

Appendix A: Available References for Information Associated with Plant and/or Pollinator Species, Interactions and Policy.

A.1 Website links

A.1.1 Drivers

Presidential Memorandum,
https://www.whitehouse.gov/the-press-office/2014/06/20/presidential-memorandum-creating-federal-strategy-promote-health-honey-b

DoD *Memorandum*,
http://www.dodpollinators.org/Pollinator_Friendly_Management_-_signed_memo001.pdf

National Strategy to Promote the Health of Honey Bees and Other Pollinators,
http://www.dodpollinators.org/Pollinator_Health_Strategy_2015_for_DoD.pdf

A.1.2 Useful Website links

A.1.2.1 Pollinators

Pollination Syndrome Traits,
http://www.pollinator.org

U.S. Department of Agriculture (USDA) "PLANTS Pollinators,"
http://plants.usda.gov/pollinators/NRCSdocuments.html

Idaho State University website,
http://www.isu.edu/~fultjess/Pollinators/

DoD Pollinator Initiatives,
http://www.dodpollinators.org/

Wisconsin Pollinators,
http://wisconsinpollinators.com/Plants/PLANTS.aspx

Insect Images,
http://www.insectimages.org/

Importance of Pollinators
http://www.wildflower.org/conservation_pollinators/

NAPPC North American Pollinator Protection Campaign,
http://www.nappc.org

Pollinator Partnership
www.pollinator.org)

The Xerces Society: Pollinator Conservation
http://www.xerces.org/pollinator-conservation

Pollination Syndrome,
http://www.fs.fed.us/wildflowers/pollinators/What_is_Pollination/syndromes.shtml

A.1.2.2 Plants

USDA "Plants,"
http://plants.usda.gov/java/

Lady Bird Johnson Wildflower Center,
http://www.wildflower.org/conservation_pollinators/

Center for Plant Conservation,
http://www.centerforplantconservation.org

A.1.2.3 Rare and Endangered Species

NatureServe Explorer,
http://explorer.natureserve.org/index.htm

Center for Biological Diversity,
http://www.biologicaldiversity.org/programs/biodiversity/species_agreement/species_list.html

A.1.2.4 Other

Zipcode,
Zoo(http://zipcodezoo.com/index.php/Main_Page)

Appendix B: *Program R* Code to Visualize and Analyze Plant-Pollinator Networks Using ‘Bipartite’ Package.

```
#####Code to Create Bipartite Networks#####

###Load the 'bipartite' package
library(bipartite)

###Read in data
#data must be a j x k matrix where j is the number plant species
#and k is the number of pollinator species
#plants are the rows and the pollinators are the columns
#the data within the matrix is either binomial (1 for interac-
tion; 0 for no interaction)
#for weighted networks, the data can be some measure of the in-
tensity of interactions
#the first column in the spreadsheet will be the plant specie
names under the header "row.names"
#the first row values after the first column will be the pollina-
tor names
obs<-read.csv("c:\\temp\\PolNet_Ma-
trix.csv,”header=TRUE,row.names="row.names")

###Use the 'plotweb' function to visualize network
plotweb(obs)

#Colors and visual representation can be altered using additional
options in the 'plotweb' function
plotweb(obs,col.low="forest-
green,”col.high="tan4,”high.y=1.4,low.y=0.65,low.spac-
ing=0.05,labsize=1.5,text.rot=90)

#There are also options within the 'plotweb' function to add
abundances of each species and other attributes
#Make sure to save final network


#Another way to visual the network is with the 'visweb' function
#This function produce a grid with shaded squares representing
interactions


###Use the 'specieslevel' function to calculate network statis-
tics for each network node (specie)
stats<-specieslevel(obs)
#the 'names' function will tell you what was calculated
names(stats)
#[1] "higher level" "lower level"

#since the product of the 'specieslevel' function is a data array
```

```
#you need to separate the two level of the network
plant.stats<-stats$'lower level'
pollinator.stats<-stats$'higher level'
#now you can use the 'names' function to see what was calculated
names(plant.stats)
# [1] "degree"                      "normalised.degree"
# [3] "species.strength"            "interaction.push.pull"
# [5] "nestedrank"                  "PDI"
# [7] "species.specificity.index"   "resource.range"
# [9] "PSI"                         "node.specialisation.in-
dex.NSI"
#[11] "betweenness"                 "weighted.betweenness"
#[13] "closeness"                   "weighted.closeness"
#[15] "Fisher.alpha"                "partner.diversity"
#[17] "effective.partners"          "proportional.similarity"
#[19] "proportional.generality"     "d"

#Network properties can be analyzed using the 'networklevel'
function
net_stats<-networklevel(obs)
names(net_stats)
# [1] "connectance"                    "web asymmetry"

# [3] "links per species"              "number of compartments"

# [5] "compartment diversity"          "cluster coefficient"

# [7] "nestedness"                     "weighted nestedness"

# [9] "weighted NODF"                  "interaction strength
asymmetry"
#[11] "specialisation asymmetry"       "linkage density"

#[13] "weighted connectance"           "Fisher alpha"

#[15] "Shannon diversity"              "interaction evenness"

#[17] "Alatalo interaction evenness"   "H2"

#[19] "number.of.species.HL"           "number.of.species.LL"

#[21] "mean.number.of.shared.partners.HL" "mean.num-
ber.of.shared.partners.LL"
#[23] "cluster.coefficient.HL"         "cluster.coefficient.LL"

#[25] "weighted.cluster.coefficient.HL"   "weighted.cluster.coef-
ficient.LL"
#[27] "niche.overlap.HL"               "niche.overlap.LL"

#[29] "togetherness.HL"                "togetherness.LL"

#[31] "C.score.HL"                     "C.score.LL"

#[33] "V.ratio.HL"                     "V.ratio.LL"
```

```
#[35] "discrepancy.HL"                    "discrepancy.LL"

#[37] "extinction.slope.HL"               "extinction.slope.LL"

#[39] "robustness.HL"                     "robustness.LL"

#[41] "functional.complementarity.HL"  "functional.complementa-
rity.LL"
#[43] "partner.diversity.HL"              "partner.diversity.LL"

#[45] "generality.HL"                     "vulnerability.LL"
```

Appendix C: Example Matrix Format for Use in Network Analyses

Table 1. Example matrix format for use in network analyses.

	Lai. spp	Dan.ple	Phy. tha	Col. phi	Sat. cal	Bom.spp	Acr. fal	Cal. iru	Cat. whi	Cha. cer	Era. col	Hes. ott	Sch. ind	Spe. ida	Lyc. melsam
Pan.qui	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eur.fur	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Tria.mo	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Cor.ame	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Cor.cor	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Bap.bra	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Bap.alb	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Lup.per	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Amo.can	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Pru.ame	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Pru.pen	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Pru.pum	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Pru.ser	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Pru.vir	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Vac.ang	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Vac.pal	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Cea.ame	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	Lai. spp	Dan.ple	Phy. tha	Col. phi	Sat. cal	Bom.spp	Acr. fal	Cal. iru	Cat. whi	Cha. cer	Era. col	Hes. ott	Sch. ind	Spe. ida	Lyc. melsam
Cea.her	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Sch.sco	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Bou.cur	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Spo.het	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Phl.pil	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Phl.div	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Phl.pan	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

	Lai. spp	Dan.ple	Phy. tha	Col. phi	Sat. cal	Bom.spp	Acr. fal	Cal. iru	Cat. whi	Cha. cer	Era. col	Hes. ott	Sch. ind	Spe. ida	Lyc. melsam
Vio.aff	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Vio.bic	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Vio.con	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Vio.cuc	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Vio.lan	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Vio.mac	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Vio.ped	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Vio.ped.1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Vio.pub	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Vio.sag	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Vio.sor	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Vio.tri	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

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14. ABSTRACT
Pollinating insects and pollinator dependent plants are critical components of functioning ecosystems yet, for many U.S. Department of Defense (DoD) installations, the identities and relationships between pollinators and plants are unknown. This study demonstrated methods for compiling and analyzing readily available information for insect pollinators and pollination dependent plants for a single installation, Fort McCoy, WI. Although installation documents identified a total of 1470 insect species and 972 plant species were identified on the installation, this work focused on species of conservation concern (nine pollinator insect species and three pollinator-associated plant species). Published information on insect pollinators and pollination dependent plants was then used to conduct a basic plant-pollinator network analyses using free analytical network software (software package R), which revealed that all the plant species of conservation concern are pollinated by several insect pollinator species. However, many pollinator insect species of conservation concern were associated with a limited number of host plant species. The results of this work suggest that analyses that rely on publicly available information provide a useful starting point in determining basic, binary plant-pollinator relationships. Field-collected data, e.g., frequency of pollinator-plant interactions, would be required for a more detailed, robust network analysis.

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