

M.L. 2014, Chp. 312, Sec. 8 Project Abstract

For the Period Ending June 30, 2019

PROJECT TITLE: Climate change and range expansion of invasive plants

PROJECT MANAGER: D. A. Moeller

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FUNDING SOURCE: Environment and Natural Resources Trust Fund

LEGAL CITATION: M.L. 2014, Chp. 312, Sec. 8

APPROPRIATION AMOUNT: \$209,263

AMOUNT SPENT: \$206,263

AMOUNT REMAINING: \$2,928

Overall Project Outcome and Results

In our project, ‘Climate change and range expansion’, our goal was to use public records of species presences and available environmental data to build models that predicted the habitat suitability and invasion risk under current and future climate scenarios for 10 invasive species of interest to MN. Those species were: Common Tansy, Wild Parsnip, Palmer Amaranth, Oriental Bittersweet, Narrowleaf Bittercress, Japanese Hops, Common Teasel, Dalmatian Toadflax, Brown Knapweed, and Black Swallowwort. We originally planned to include Grecian Foxglove, but were unable to obtain enough data to build reliable models. We developed species distribution models (SDMs) using multiple techniques (Maxent, Boosted Regression Trees, and Joint Distribution Modeling of Communities) and multiple scales (North American continent and Upper Midwest) to validate results. We wrote a report with detailed finding from our SDMs titled, “Species Distribution Model Projections for Incipient Invasive Species of Minnesota”. Our findings can be used to help guide management decisions about surveillance and eradication efforts for these species. Additionally, we have published on our findings on methods for producing accurate models of invasive species and specific SDMs for the species of interest in academic peer-reviewed journals. We have also presented our work at the UMISC-NAISMA and Palmer Amaranth Conferences and have participated as presenters in USFS land manager training. The project supported or trained one postdoctoral scholar, one postgraduate research assistant, two undergraduate students, and one graduate student. One undergraduate student decided to continue as a graduate student working on invasive species and is an author on all of the manuscripts and data products. The management document and all of the underlying data, models, and projections are archived at the Data Repository for U of M (DRUM) and are freely available to Minnesotans to access to gain a better picture of the potential distributions of the listed species.

Project Results Use and Dissemination

Our project has resulted in four publications, five major presentations to disseminate our findings at national and regional meetings, and 80 data products that can be accessed by all Minnesotans and natural resource professionals (detailed list below). We have published our SDM results for Palmer amaranth in the open-access journal *Scientific Reports*, which is freely available to the public. We have presented the result of this paper at the UMISC-NAISMA Joint Conference in Oct 2018 in the Palmer amaranth session to scientists and

professionals interested in the problem of rapid, invasive spread of Palmer amaranth. We also presented to work as a poster at the first MITPPC Palmer Amaranth Summit in Jan 2019 and Dr. Briscoe Runquist participated in the conference management working groups as scientific expert on the biology and potential for spread of the species. We have also presented this work to the MN NWAC Management and Policy Subcommittee. Additionally, we provided training to US Forest Service professionals about the underlying mechanics of species distribution models and how and when they can be used to effectively forecast and manage the spread of invasive species under current and future climate conditions. Lastly, we produced a document specific to predicted habitat suitability in MN to be used by MN natural resource professionals for surveillance and eradication decision-making. This document will be housed with the MITPPC in hard copy form and will be accessible as a pdf on their website for download.

During the course of this project, we have generated 80 multi-layered data products that have been archived at the Data Repository for U of M (DRUM; detailed table below) with DOI numbers that can be used to quickly access the data. These data products can be used for further analyses for researchers and natural resource professionals. For each of the species, we have collated a list of occurrence records (current through 2018) that are sourced from multiple databases and have been cleaned for problematic records. They are ready for use in multiple applications that require verified occurrence data. We have also generated multiple SDMs, their validation metrics, and current and future projections based on these models for all ten species. We have provided the models and the raster projections for these SDMs as downloadable files. Further, for 3 species, Narrowleaf Bittercress, Oriental Bittersweet, and Japanese Hops, we developed Joint Species Distribution models (JSDMs) to compare with traditional SDMs using DNR relevé data, environmental data, and a Bayesian method for joint attribute modeling. The input data (climate data, species co-occurrence matrices) and output data (models and projections) are also available for use. These models provide data on projections for the invasive species, as well as for other potential plant community members of interest.

Published Manuscripts:

Briscoe Runquist, R. D., T. Lake, P. Tiffin, and D. A. Moeller. 2019. Species distribution models throughout the invasion history of Palmer amaranth predict regions at risk of future invasion and reveal challenges with modeling rapidly shifting geographic ranges. *Scientific Reports*, 9: 2426

Manuscripts in prep:

Lake, T., R. D. Briscoe Runquist, and D. A. Moeller. Predicting ranges of invasive species with complicated invasion histories. *Target Journal: Ecography*

Briscoe Runquist, R. D., T. Lake, and D. A. Moeller. Joint species distribution modeling of invasive species: a viable biologically informed alternative? *Target Journal: Biological Invasions*

Manuscripts for MN Management Decision Makers:

Briscoe Runquist, R. D., T. Lake, and D. A. Moeller. 2019. Species distribution model projections for incipient invasive species of Minnesota.

Contributed Oral and Poster Presentations:

Moeller, D.A. "Speciation and the evolution of geographic range limits in narrowly endemic plant species: implications for conservation". Seminar for *National Tropical Botanical Garden, Hawaii*, 26 Feb. 2019 (Section on SDM development for native and invasive species with reference to MITPPC work)

Briscoe Runquist, R. D., T. Lake, P. Tiffin, and D. A. Moeller. "Species distribution models throughout the invasion of Palmer amaranth predict regions at risk of future invasion and reveal challenges with modeling rapidly shifting geographic ranges". *Palmer Amaranth Summit*, 22 Jan. 2019

Briscoe Runquist, R. D., P. Tiffin, and D. A. Moeller. "Species distribution models of multiple states of invasion in Palmer amaranth". *UMISC - NAISMA Joint Conference*, 17 Oct. 2018

Moeller, D. A. and R. D. Briscoe Runquist. "Climate change and range expansion of invasive plants", *NWAC Management and Policy Subcommittee Meeting*, 25 April 2018

Briscoe Runquist, R. D. and D. A. Moeller. "Climate change and range expansion of invasive plants", *Climate Change Training for US Forest Service Managers*, 27 Feb. 2018

Outreach Activities:

"Detecting invasive species in MN", CBS Market Science Outreach Table at Nokomis Farmer's Market, Aug. 2016

Press Articles:

"Evaluating Species Distribution Models". *UMN MSI Website*, 7/31/19,
<https://www.msi.umn.edu/research/evaluating-species-distribution-models>

"UMN researchers predict spread of invasive plant species into Minnesota". *Minnesota Daily*, 3/3/19,
<https://www.mndaily.com/article/2019/03/n-umn-researchers-predict-spread-of-invasive-plant-species-into-minnesota>

Data Products:

Table 1. Detailed list of all files uploaded to the Data Repository for U of M (DRUM)*

Meta	File Name	Description	File Contents
Current and Future Bioclimatic Variables	NA_wc2_BioClim19.grd	WorldClim v2 Bioclimatic Dataset	.GRD File containing current WorldClim v2 bioclimatic layers used to construct MaxEnt models
	NA_wc2_BioClim19.gri	WorldClim v2 Bioclimatic Dataset	.GRI File containing current WorldClim v2 bioclimatic layers used to construct MaxEnt models
	NA_cc45bi50_BioClim19.grd	CCSM4 Future Climate Scenario 2050	.GRI File containing future 2050 CCSM4 projection bioclimatic layers used to construct MaxEnt models
	NA_cc45bi50_BioClim19.gri	CCSM4 Future Climate Scenario 2050	.GRD File containing future 2050 CCSM4 projection bioclimatic layers used to construct MaxEnt models
	NA_cc45bi70_BioClim19.grd	CCSM4 Future Climate Scenario 2070	.GRI File containing future 2070 CCSM4 projection bioclimatic layers used to construct MaxEnt models
	NA_cc45bi70_BioClim19.gri	CCSM4 Future Climate Scenario 2070	.GRD File containing future 2070 CCSM4 projection bioclimatic layers used to construct MaxEnt models
	NA_gd45bi50_BioClim19.grd	GFDL Future Climate Scenario 2050	.GRI File containing future 2050 GFDL projection bioclimatic layers used to construct MaxEnt models
	NA_gd45bi50_BioClim19.gri	GFDL Future Climate Scenario 2050	.GRD File containing future 2050 GFDL projection bioclimatic layers used to construct MaxEnt models
	NA_gd45bi70_BioClim19.grd	GFDL Future Climate Scenario 2070	.GRI File containing future 2070 GFDL projection bioclimatic layers used to construct MaxEnt models
	NA_gd45bi70_BioClim19.gri	GFDL Future Climate Scenario 2070	.GRD File containing future 2070 GFDL projection bioclimatic layers used to construct MaxEnt models
	NA_ip45bi50_BioClim19.grd	IPSL Future Climate Scenario 2050	.GRI File containing future 2050 IPSL projection bioclimatic layers used to construct MaxEnt models
	NA_ip45bi50_BioClim19.gri	IPSL Future Climate Scenario 2050	.GRD File containing future 2050 IPSL projection bioclimatic layers used to construct MaxEnt models
	NA_ip45bi70_BioClim19.grd	IPSL Future Climate Scenario 2070	.GRI File containing future 2070 IPSL projection bioclimatic layers used to construct MaxEnt models
	NA_ip45bi70_BioClim19.gri	IPSL Future Climate Scenario 2070	.GRD File containing future 2070 IPSL projection bioclimatic layers used to construct MaxEnt models
	NA_mr45bi50_BioClim19.grd	MIROC Future Climate Scenario 2050	.GRI File containing future 2050 MIROC projection bioclimatic layers used to construct MaxEnt models
	NA_mr45bi50_BioClim19.gri	MIROC Future Climate Scenario 2050	.GRD File containing future 2050 MIROC projection bioclimatic layers used to construct MaxEnt models

	NA_mr45bi70_BioClim19.grd	MIROC Future Climate Scenario 2070	.GRI File containing future 2070 MIROC projection bioclimatic layers used to construct MaxEnt models
	NA_mr45bi70_BioClim19.gri	MIROC Future Climate Scenario 2070	.GRD File containing future 2070 MIROC projection bioclimatic layers used to construct MaxEnt models
	NA_mg45bi50_BioClim19.grd	MRI Future Climate Scenario 2050	.GRI File containing future 2050 MRI projection bioclimatic layers used to construct MaxEnt models
	NA_mg45bi50_BioClim19.gri	MRI Future Climate Scenario 2050	.GRD File containing future 2050 MRI projection bioclimatic layers used to construct MaxEnt models
	NA_mg45bi70_BioClim19.grd	MRI Future Climate Scenario 2070	.GRI File containing future 2070 MRI projection bioclimatic layers used to construct MaxEnt models
	NA_mg45bi70_BioClim19.gri	MRI Future Climate Scenario 2070	.GRD File containing future 2070 MRI projection bioclimatic layers used to construct MaxEnt models
MaxEnt Bias Files	knapweed_gdk_1.tif	Brown Knapweed GKD Lambda 1 Bias File	Raster .TIF file for MaxEnt background bias
	knapweed_gdk_3.tif	Brown Knapweed GKD Lambda 3 Bias File	Raster .TIF file for MaxEnt background bias
	parsnip_gdk_1.tif	Wild Parsnip GKD Lambda 1 Bias File	Raster .TIF file for MaxEnt background bias
	parsnip_gdk_3.tif	Wild Parsnip GKD Lambda 3 Bias File	Raster .TIF file for MaxEnt background bias
	swallowwort_gdk_1.tif	Black Swallowwort GKD Lambda 1 Bias File	Raster .TIF file for MaxEnt background bias
	swallowwort_gdk_3.tif	Black Swallowwort GKD Lambda 3 Bias File	Raster .TIF file for MaxEnt background bias
	tansy_gdk_1.tif	Common Tansy GKD Lambda 1 Bias File	Raster .TIF file for MaxEnt background bias
	tansy_gdk_3.tif	Common Tansy GKD Lambda 3 Bias File	Raster .TIF file for MaxEnt background bias
	teasel_gdk_1.tif	Common Teasel GKD Lambda 1 Bias File	Raster .TIF file for MaxEnt background bias
	teasel_gdk_3.tif	Common Teasel GKD Lambda 3 Bias File	Raster .TIF file for MaxEnt background bias
	toadflax_gdk_1.tif	Dalmatian Toadflax GKD Lambda 1 Bias File	Raster .TIF file for MaxEnt background bias
	toadflax_gdk_3.tif	Dalmatian Toadflax GKD Lambda 3 Bias File	Raster .TIF file for MaxEnt background bias

Occurrence Data	bittercress_occurrences.csv	Narrowleaf Bittercress Latitude Longitude Occurrences	Latitude and Longitude point occurrences of species used to construct MaxEnt models
	bittersweet_occurrences.csv	Oriental Bittersweet Latitude Longitude Occurrences	Latitude and Longitude point occurrences of species used to construct MaxEnt models
	black_swallowwort_occurrences.csv	Black Swallowwort Latitude Longitude Occurrences	Latitude and Longitude point occurrences of species used to construct MaxEnt models
	brown_knapweed_occurrences.csv	Brown Knapweed Latitude Longitude Occurrences	Latitude and Longitude point occurrences of species used to construct MaxEnt models
	common_tansy_occurrences.csv	Common Tansy Latitude Longitude Occurrences	Latitude and Longitude point occurrences of species used to construct MaxEnt models
	common_teasel_occurrences.csv	Common Teasel Latitude Longitude Occurrences	Latitude and Longitude point occurrences of species used to construct MaxEnt models
	dalmatian_toadflax_occurrences.csv	Dalmatian Toadflax Latitude Longitude Occurrences	Latitude and Longitude point occurrences of species used to construct MaxEnt models
	japanese_hops_occurrences.csv	Japanese Hops Latitude Longitude Occurrences	Latitude and Longitude point occurrences of species used to construct MaxEnt models
	wild_parsnip_occurrences.csv	Wild Parsnip Latitude Longitude Occurrences	Latitude and Longitude point occurrences of species used to construct MaxEnt models
MaxEnt Predictions	Bittercress Tif Projection Stack.tif	Narrowleaf Bittercress Raster Prediction TIF Files in Raster Stack	Stack of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios
	Bittersweet Tif Projection Stack.tif	Oriental Bittersweet Raster Prediction TIF Files in Raster Stack	Stack of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios
	Hops Tif Projection Stack.tif	Japanese Hops Raster Prediction TIF Files in Raster Stack	Stack of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios
	Knapweed Tif Projection Stack.tif	Brown Knapweed Raster Prediction TIF Files in Raster Stack	Stack of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios
	Parsnip Tif Projection Stack.tif	Wild Parsnip Raster Prediction TIF Files in Raster Stack	Stack of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios
	Swallowwort Tif projection Stack.tif	Black Swallowwort Raster Prediction TIF Files in Raster Stack	Stack of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios

	Tansy Tif projection Stack.tif	Common Tansy Raster Prediction TIF Files in Raster Stack	Stack of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios
	Teasel Tif Projection Stack.tif	Common Teasel Raster Prediction TIF Files in Raster Stack	Stack of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios
	Toadflax Tif Projection Stack.tif	Dalmatian Toadflax Raster Prediction TIF Files in Raster Stack	Stack of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios
MaxEnt Predictions	Bittercress Tif Projection Stack Files.csv	Narrowleaf Bittercress Raster Prediction TIF Files in Raster Stack	File names of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios
	Bittersweet Tif Projection Stack Files.csv	Oriental Bittersweet Raster Prediction TIF Files in Raster Stack	File names of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios
	Hops Tif Projection Stack Files.csv	Japanese Hops Raster Prediction TIF Files in Raster Stack	File names of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios
	Knapweed Tif Projection Stack Files.csv	Brown Knapweed Raster Prediction TIF Files in Raster Stack	File names of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios
	Parsnip Tif Projection Stack Files.csv	Wild Parsnip Raster Prediction TIF Files in Raster Stack	File names of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios
	Swallowwort Tif Projection Stack Files.csv	Black Swallowwort Raster Prediction TIF Files in Raster Stack	File names of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios
	Tansy Tif Projection Stack Files.csv	Common Tansy Raster Prediction TIF Files in Raster Stack	File names of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios
	Teasel Tif Projection Stack Files.csv	Common Teasel Raster Prediction TIF Files in Raster Stack	File names of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios
	Toadflax Tif Projection Stack Files.csv	Dalmatian Toadflax Raster Prediction TIF Files in Raster Stack	File names of current and future raster TIF habitat suitability predictions generated from MaxEnt models under multiple MaxEnt model scenarios

JSDM Raster Projection Files

Carlmp_FullState_19Feb2019.grd	Narrowleaf Bittercress JSDM Raster Prediction Tif for Full State	Raster TIF File for JSDM Prediction
Carlmp_FullState_19Feb2019.gri	Narrowleaf Bittercress JSDM Raster Prediction Tif for Full State	Raster TIF File for JSDM Prediction
Carlmp_Part State_19Feb2019.grd	Narrowleaf Bittercress JSDM Raster Prediction Tif for Partial State	Raster TIF File for JSDM Prediction
Carlmp_PartState_19Feb2019.gri	Narrowleaf Bittercress JSDM Raster Prediction Tif for Partial State	Raster TIF File for JSDM Prediction
Carlmp_SppBox_19Feb2019.grd	Narrowleaf Bittercress JSDM Raster Prediction Tif for Bounding Box	Raster TIF File for JSDM Prediction
Carlmp_SppBox_19Feb2019.gri	Narrowleaf Bittercress JSDM Raster Prediction Tif for Bounding Box	Raster TIF File for JSDM Prediction
CelOrb_FullState_19Feb2019.grd	Oriental Bittersweet JSDM Raster Prediction Tif for Full State	Raster TIF File for JSDM Prediction
CelOrb_FullState_19Feb2019.gri	Oriental Bittersweet JSDM Raster Prediction Tif for Full State	Raster TIF File for JSDM Prediction
CelOrb_Part State_19Feb2019.grd	Oriental Bittersweet JSDM Raster Prediction Tif for Partial State	Raster TIF File for JSDM Prediction
CelOrb_PartState_19Feb2019.gri	Oriental Bittersweet JSDM Raster Prediction Tif for Partial State	Raster TIF File for JSDM Prediction
CelOrb_SppBox_19Feb2019.grd	Oriental Bittersweet JSDM Raster Prediction Tif for Bounding Box	Raster TIF File for JSDM Prediction
CelOrb_SppBox_19Feb2019.gri	Oriental Bittersweet JSDM Raster Prediction Tif for Bounding Box	Raster TIF File for JSDM Prediction
Hum_Jap_FullState_19Feb2019.grd	Japanese Hops JSDM Raster Prediction Tif for Full State	Raster TIF File for JSDM Prediction
Hum_Jap_FullState_19Feb2019.gri	Japanese Hops JSDM Raster Prediction Tif for Full State	Raster TIF File for JSDM Prediction

Hum_Jap_Part State_19Feb2019.grd	Japanese Hops JSDM Raster Prediction Tif for Partial State	Raster TIF File for JSDM Prediction
Hum_Jap_PartState_19Feb2019.gri	Japanese Hops JSDM Raster Prediction Tif for Partial State	Raster TIF File for JSDM Prediction
Hum_Jap_SppBox_19Feb2019.grd	Japanese Hops JSDM Raster Prediction Tif for Bounding Box	Raster TIF File for JSDM Prediction
Hum_Jap_SppBox_19Feb2019.gri	Japanese Hops JSDM Raster Prediction Tif for Bounding Box	Raster TIF File for JSDM Prediction
JSDM file upload metadata.xlsx	Metadata file for JSDM raster prediction TIFs	Excel file for JSDM data

* We have uploaded all data products as a zip file to DRUM, doi:10.XXXX