ENGAGING RESIDENTS WITH LOCAL PEST MANAGEMENT AND CONSERVATION GOALS

VATSAL PARIKH
CLC FELLOW
JUSTIN GISH
MENTOR
DR. LAURA ILES
TECHNICAL ADVISOR

2024 CATALYST LEADERSHIP CIRCLE FELLOWSHIP

THE CITY OF Kalamazoo

GRAHAM SUSTAINABILITY INSTITUTE
UNIVERSITY OF MICHIGAN

EGLE
MICHIGAN DEPARTMENT OF ENVIRONMENT, GREAT LAKES, AND ENERGY

CATALYST COMMUNITIES

This material is based upon work supported by the Department of Energy and the Michigan Energy Office (MEO) under Award Number EE0008653 as part of the Catalyst Communities program. Find this document and more about the CLC Fellowship that supported this project at graham.umich.edu/clcf.

TABLE OF CONTENTS

A Note For Other Cities

These materials were created for the City of Kalamazoo but are designed to be replicated by other cities in Michigan. When reproducing, follow these procedures:

1. Visit this project's page on https://graham.umich.edu/projects?keywords=&priority=All&program=25834.
2. Download the second deliverable which is a ZIP file containing 1) GIS models and 2) Public-facing materials without Kalamazoo Branding.
3. Use the tutorials in this guidebook to reproduce any city-specific flyers or spatial analysis.

The Kalamazoo County Environmental Health Division monitors mosquito and tick presence. This signage displays an exposure warning placed in Kalamazoo's Kleinstuck Preserve.

VECTOR BORNE DISEASE + PEST MANAGEMENT + ECOLOGICAL SYSTEMS

West Nile Virus, Eastern Equine Encephalitis (EEE), and Lyme Disease are amongst the mosquito and tick-borne diseases detected in Michigan. In recent years an uptick in EEE cases has resulted in both human and livestock deaths in the state. In response, the Michigan Department of Health and Human Services has established the Vector-Borne Disease Surveillance and Prevention (VBDSP) Project to monitor the presence of these emerging diseases across the state.

Environmental stressors including climate change are projected to compound exposure risk. Warmer temperatures can increase mosquito and tick activity. Meanwhile, droughts and severe storms can create breeding sites by stagnating water bodies or by creating new water pools. Further, notable vector species, such as the common house mosquito (culex pipiens), can thrive in urban areas devoid of natural predators.

Understanding the environmental conditions that modulate vector populations is a crucial step for communities to strategically address this issue. This guide outlines a multi-pronged programming that municipalities can use to engage residents with sustainable pest-management solutions — specifically for mosquitoes.

A Systems View

During outbreaks, governments sometimes conduct aerial and truck spraying of insecticides such as pyrethrins and pyrethroids. While these chemicals can reduce the symptom of pest abundance, they only reduce adult mosquitoes temporarily because they do not, in isolation, address the source of the problem. Overuse can also lead to insecticide resistance which reduces the long-term efficacy of this approach. Removing anthropogenic sources of mosquito breeding and personal protection are among the most effective ways to reduce mosquito bites.

On contact and when they run off into waterways, insecticides can adversely impact non-target insects, amphibians, and reptiles — some of which are endangered or provide important ecosystem services such as pest control and pollination.

Many birds and bats also prey on a variety of pests. Some species in Michigan, such as the little brown bat and the purple martin, are even known to include mosquitoes in their diet. Although no single species eliminates mosquitoes through predation, they can help manage abundance while providing broader economic impacts. It is estimated for example, that bats provide billions of dollars in savings to U.S. agriculture by reducing pest-related crop damage and pesticide application. However, many bat species have quietly suffered devastating population declines due to a combination of habitat loss and introduced diseases.

Community Involvement

Municipal governments in Michigan can strive towards sustainable pest management by targeting the sources of pest abundance and conserving key ecosystem services. Accordingly, the program outlined here aims to provide residents systems-level awareness, public engagement, and tools for local-scale action.

The program should include both initiatives that are easy to adopt and provide direct benefit, and initiatives that contribute to long-term ecological resilience through more active engagement.

The outlined initiatives are:

1. Understanding the public health and ecological dimensions of local Vector-Borne Diseases
2. Integrated Pest Management strategies to directly reduce exposure
3. Strategies for building community-wide ecological resilience to mosquito abundance
4. Conservation and coexistence of threatened species involved in pest control

The subsequent sections will explain these components in greater detail. City-branded materials can be used for public-facing distribution and communication of these topics.

Systems Considerations of Mosquito Management

Human activities have indirect effects on mosquito abundance. While insecticides can help reduce mosquito abundance upon application, long-term mosquito management is more effective when approached comprehensively.
To steward a mosquito-resilient ecosystem in your community, consider practicing Integrated Pest Management and participating in local habitat restoration efforts for natural mosquito predators.

Pesticides

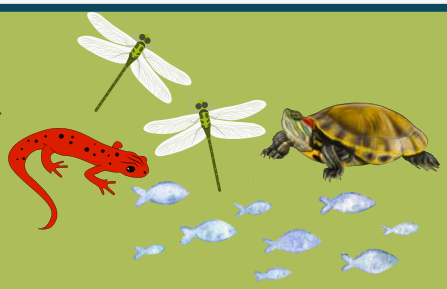
Mosquito adulticides such as organophosphates and pyrethroids have broad-spectrum toxicity and can kill non-target organisms including pollinators and other federally endangered insects. They can have notably wide-reaching effects when they run off into waterways.

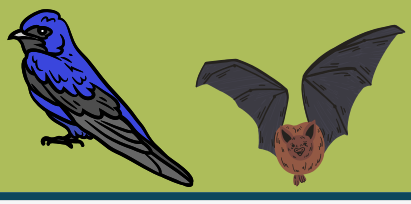
Litter

Mosquitoes can breed in very small pools of water. When items such as old tires, buckets, or litter collect water, they can become breeding grounds for mosquitoes, particularly because they lack natural predators.

Larval Predation in Aquatic Habitat

Aquatic organisms such as dragonflies, fish, amphibians, and turtles can help control mosquito populations by consuming larvae or adults during different stages of their life cycle. While wetlands do have standing water, those with diverse ecological communities can have minimal mosquito production. However, insecticide or fertilizer runoff into wetlands can harm these organisms through toxicity or the creation of eutrophic conditions.





Adult Mosquito Predation in Terrestrial Systems

Many species of birds and bats prey on pests, including mosquitoes. Did you know that annually bats provide billions of dollars of agricultural benefits in the United States by reducing crop damage and the need for pesticide application? Some Michigan species such as the purple martin and the little brown bat are known to include mosquitoes in their diets. They won't eliminate mosquitoes on their own, but together, natural predators play an important role in controlling adult mosquitoes.

Habitat Degradation

Habitat loss is a leading threat to bats and birds in the United States. Habitat loss can come in different forms such as the clearing of trees which removes available roosting sites, development that fragments available habitat, or pollution that reduces survival of species in an area.

Climate Change

Warming climates can contribute to extended and more active mosquito seasons. Climate change can also cause more droughts and severe storms. Did you know that both of these conditions can drive mosquito breeding by increasing pools of standing water?

THE CITY OF Kalamazoo

INSERT QR CODE HERE

SYSTEMS CONSIDERATIONS

The following resources can be made available for residents on Kalamazoo's sustainability webpage, which can be linked in the QR codes.

Insecticide use and externalities

Insecticide resistance

- https://www.ars.usda.gov/news-events/news/research-news/2019/mosquitoes-show-high-resistance-to-common-insecticide/

Michigan statement on aerial spraying to combat EEE

- https://www.michigan.gov/emergingdiseases/home/eastern-equine-encephalitis/eee-press-releases/aerial-spraying-being-conducted-in-14-counties-to-combat-mosquito-borne-disease

Information for Michigan insecticide applicators

- https://www.fws.gov/sites/default/files/documents/information-for-michigan-insecticide-applicators-2024.pdf
- https://storymaps.arcgis.com/stories/8a371d4283e04a6ca3c0323b84d846eb

National Pollutant Discharge Elimination System (NPDES) permit for the application of pesticides

- https://www.michigan.gov/egle/about/organization/water-resources/npdes/pesticide-control

EPA safe pest control

- https://www.epa.gov/safepestcontrol

Xerces Society reducing pesticide use and at-risk invertebrates

- https://www.xerces.org/pesticides
- https://www.xerces.org/endangered-species/species-profiles

Understanding ecosystem services for pest management

Effectiveness of dragonflies and damselflies as part of mosquito management systems:

- https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2656.13965
- https://pubmed.ncbi.nlm.nih.gov/37272224/

Pest Consumption by Bats

- https://www.usgs.gov/faqs/why-are-bats-important
- https://www.popsci.com/bats-are-worth-1-billion-to-corn-industry/
- https://www.batcon.org/about-bats/bats-101/

USDA Bat Value Calculation Activity for Grade School Students

- https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd476773.pdf

Climate Change, habitat loss, and indirect impacts to pest abundance

- **Habitat loss for bats**
  - https://www.nps.gov/subjects/bats/habitat-loss.htm
- **Habitat quality influences bat dietary choices**
  - https://onlinelibrary.wiley.com/doi/full/10.1111/j.1365-294X.2011.05040.x
- **Pesticide impacts on bats may be under studied**
  - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7009170/
- **Habitat loss for birds**
  - https://www.fws.gov/library/collections/threats-birds
- **Indirect Effects of Pesticides on Insects and Other Arthropods**
  - https://www.mdpi.com/2305-6304/9/8/177

Integrated Pest Management (IPM)

BENEFITS OF IPM

Integrated Pest Management is an effective pest control approach that aims to minimize environmental impacts by using knowledge of pest life cycles and ecology to target the problem sources. IPM prioritizes multi-pronged strategies to reduce pest habitat and breeding conditions prior to using potentially harmful chemical interventions. The IPM framework can be adapted to household or agricultural scales and its steps can be taken individually or distributed amongst stakeholders. For residents seeking to become involved, it is important to first recognize how IPM responsibilities are distributed across their community, and second identify the most actionable measures that they can take.

WHAT ASPECTS ARE ONGOING?

As part of the Vector-Borne Disease Surveillance and Prevention Project, the Michigan Department of Health and Human Services (MDHHS) works with the Kalamazoo County Health Department's Environmental Health division to collect weekly data on mosquito and tick species. Samples collected in this process are tested for vector-borne diseases. Communications from this study provide the public up-to-date guidance on which species to be concerned about and the conditions under which they should take precautions.

These communications can be found by visiting:
https://www.michigan.gov/emergingdiseases

HOW CAN RESIDENTS PARTICIPATE?

While the state of vectors in an area can change, general IPM strategies for mosquitoes and ticks have a low barrier to entry, provide direct benefits, and are recommended for broad adoption. The flyers in the following pages are meant to create awareness about these broadly-effective tactics and can be distributed in public spaces, the city's website, or via social media channels. Sharing additional reading materials from trusted sources, like the EPA, can help residents learn the intricacies of the issues and seek additional solutions per their unique needs.

FOCUS AREAS FOR RESIDENTS

- Protect self with structural barriers and EPA-registered repellents.
- Reduce pest habitat and breeding sites.
- Learn more about the causes and risk factors associated with vector-borne diseases.
- Address misconceptions about pest management solutions.

IPM FRAMEWORK

1. SET ACTION THRESHOLDS

In situations where pest abundance or interactions with humans is low, occurrence may not necessarily be harmful. Guidelines from MDHHS can inform when action is most important.

2. MONITOR AND IDENTIFY PESTS

There are over 60 species of mosquitoes found in Michigan. Each species has variation in its habitat preference and differs in the diseases it can transmit. Awareness of species-specific presence can inform targeted management strategies. Residents can search their property for species of concern and their specific breeding habitats. MDHHS provides county-level pest monitoring information which is relevant to a wide audience. Residents can also conduct smaller-scale monitoring to evaluate localized pest concerns.

3. PREVENT

After identifying pests of concern, the next step is to reduce pest-specific habitat and breeding sites. Further, measures should be taken to reduce the likelihood of the pest interacting with humans, domestic animals, or crops. These strategies can vary between residential and agricultural contexts, and across pest species.

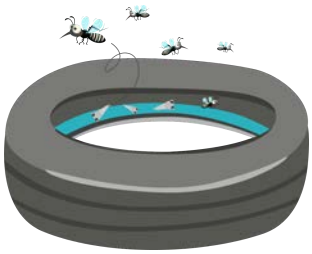
4. CONTROL

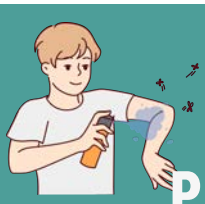
IPM prioritizes the use of targeted biological controls before the use of insecticides. For mosquitoes, if insecticides are used, larvicides are prioritized over adulticides as they can be applied in smaller quantities and generally contribute less significant impacts to nontarget species. Finally, all insecticide use should involve EPA-registered products and applications should strictly follow label instructions. Consultation with a pest control professional is recommended whenever adulticide use is pursued.

STAY PROTECTED AGAINST MOSQUITOES

INTEGRATED PEST MANAGEMENT

Mosquito-borne diseases are emerging public health concerns. Minimizing human and livestock exposure to mosquito bites is critical to reducing cases of Eastern Equine Encephalitis, West Nile Virus, and other vector-borne diseases in Michigan. While insecticides can provide temporary relief from mosquito abundance, when used in isolation their effects can be temporary. They can also have ecological consequences. The EPA and CDC recommend Integrated Pest Management, which is a scientifically-proven framework that first targets natural processes within pest lifecycles. Public adoption of preventative measures is necessary for community-wide integrated mosquito management.





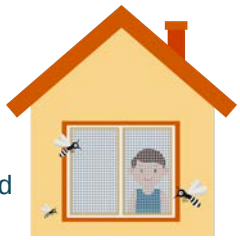
BITE PROTECTION

- Mosquitoes are most active in Michigan during the summer months and can be populous near permanent water bodies.
- Minimize exposed skin by wearing long-sleeved shirts, pants, and head nets to help reduce bites.
- Applying EPA-registered mosquito repellents in accordance to label directions can also safely and effectively protect against bites.

ELIMINATE BREEDING HABITAT

Mosquitoes can rapidly breed in small pools of standing water. Common items within which water can collect include buckets, litter, rain gutters, old tires, plastic covers, and toys. Remove these items from outdoor spaces exposed to rain. In fixtures meant to hold water — such as bird baths, fountains, wading pools, or rain barrels — replace water weekly. Swimming pools should be treated and circulating.

STRUCTURAL BARRIERS



Physical barriers can reduce the likelihood of indoor mosquito bites. Effective strategies include installing window and door screens, covering gaps in walls, and covering baby carriers and beds with mosquito nets. Using fans during outdoor gatherings can also help blow away mosquitoes from the area.

LARVAL STAGE CONTROL

Mosquitoes are most concentrated and accessible during their larval stage. “Mosquito dunk” tablets containing EPA-registered strains of Bti (Bacillus thuringiensis - a naturally occurring bacterium found in soils) can be effective larvicides. Bti produces spores that target mosquitoes rather than other species. Add water and straw (or leaves) to a bucket to attract mosquitoes. After 2-4 days, add a mosquito dunk to the bucket. Make sure to follow the product label! These traps can last up to a month and should then be poured out and replaced.

ADULT STAGE CONTROL

There are many misconceptions surrounding the use of insecticides in mosquito control. In a residential setting, sprays and outdoor foggers lack extensive study and are only effective in reducing mosquito presence briefly after application. Focusing on the previous steps is recommended. If utilizing pesticides, consult a professional and only apply EPA-registered products per their label instructions.

THE CITY OF Kalamazoo

INSERT QR CODE HERE

STAY PROTECTED AGAINST TICKS

INTEGRATED PEST MANAGEMENT

Cases of tick-borne illnesses, such as Lyme Disease, are increasing in the United States due to a variety of factors. Tick distribution can expand due to climate change and land use patterns that increase their activity and ability to occupy new habitats. The EPA recommends Integrated Pest Management strategies that aim to minimize human-tick interaction by comprehensively utilizing tick monitoring, preventative strategies, and tick control. Public engagement with preventative strategies is a key step in this process.

LANDSCAPING PRACTICES

Knowing where ticks may exist in your yard can help guide how you interface with them. Ticks are often found in leaf litter, brush, and weeds at the edge of a lawn. Create a 9-foot buffer zone between such areas and places utilized for recreation. Around frequented areas:

- Apply 3-foot wide mulch barrier along forest edge
- Remove leaf litter, brush and weeds
- Keep grass mowed (less than 3 inches)
- Keep vegetation trimmed near edge of lawn

IMAGE SOURCE: HTTPS://WWW.EPA.GOV/SITES/DEFAULT/FILES/2014-11/DOCUMENTS/TICK-SAFETY-IN-SCHOOLS.PDF

BITE PROTECTION

- In Michigan ticks are most active between early May and November. They are commonly found in forests and grassy areas.
- When entering tick habitat, wear long-sleeved shirts, pants, and boots. Tuck shirts into pants and pants into long socks to seal points of entry. Wear light-colored clothing for easy tick checks.
- DEET-based repellents can be used on self while permethrin-based repellents can be used on clothing. Always apply in accordance to label directions!
- To remove ticks, grasp them with tweezers close to the skin and steadily pull upwards. Sanitize the site with soap and water or rubbing alcohol.
- DO NOT crush ticks with your hands. Instead flush them down the toilet or dispose in a sealed bag.
- If bitten, consider bringing the tick in a sealed bag to a medical professional. Identification of the tick can assist medical diagnosis.

LEARN MORE: WWW.CDC.GOV/TICKS

REDUCE TICK TRANSPORT

Ticks can also be transported on common host animals such as deer, chipmunks, and mice. Try to remove wood piles and other similar structures that mice may seek shelter in. Further, consider restricting deer accessibility to to gardens and frequented spaces. This can include the use of fencing around vegetable gardens (ideally 8-foot in height). Deer resistant plants can also be used to deter deer from select areas.

REPLACING INVASIVE PLANTS

Studies have found that several species of invasive plants can harbor high tick densities. Consider replacing Honeysuckle and Japanese Barberry with native plants. Areas abundant in Honeysuckle may have 10 times greater risk of tick exposure, whereas plots abundant with with Japanese Barberry may have up to 60% greater tick exposure!

THE CITY OF Kalamazoo

INSERT QR CODE HERE

INTEGRATED PEST MANAGEMENT

The following resources can be made available for residents on Kalamazoo's sustainability webpage, which can be linked in the QR codes.

Pests and Vector-Borne Disease

Michigan Emerging Diseases

- https://www.michigan.gov/emergingdiseases
- https://www.michigan.gov/emergingdiseases/-/media/Project/Websites/emergingdiseases/EZID_Annual_Surveillance_Summary.pdf?rev=26725ec88cf545d980d5dbeec7c7f53a

Trends in tick-borne disease and tick identification

- https://www.michigan.gov/emergingdiseases/-/media/Project/Websites/emergingdiseases/Folder3/2021_Tickborne_Disease_Summary_Report.pdf
- https://www.michigan.gov/-/media/Project/Websites/emergingdiseases/Folder1/Tick_ID_Card_Web.jpg

Integrated Pest Management

EPA Integrated Pest Management Fact Sheet

- https://19january2021snapshot.epa.gov/sites/static/files/2017-08/documents/ipm-factsheet.pdf

USDA Integrated Pest Management National Roadmap

- https://www.usda.gov/oce/pest/integrated-pest-management

Michigan Integrated Pest Management Program Manual

- https://www.michigan.gov/-/media/Project/Websites/mdard/documents/pesticide-plant-pest/pesticide/ipm_program_information_template.pdf

EPA Mosquito Control

- https://www.epa.gov/mosquitocontrol/general-information-about-mosquitoes
- https://www.epa.gov/mosquitocontrol/success-mosquito-control-integrated-approach

CDC Mosquito Bite Prevention

- https://www.cdc.gov/mosquitoes/prevention/index.html

Xerces Society Effective Mosquito Management

- https://www.xerces.org/pesticides/effective-mosquito-management

CDC Tick Lifecycles

- https://www.cdc.gov/ticks/prevention/index.html
- https://www.cdc.gov/ticks/about/tick-lifecycles.html

Michigan Tick Safety

- https://www.michigan.gov/mdhhs/safety-injury-prev/environmental-health/topics/mitracking/ticks

EPA IPM for ticks

- www.epa.gov/pesp/reducing-risk-tick-borne-diseases-through-smart-safe-and-sustainable-pest-control

Tick-Borne Disease Integrated Pest Management White Paper

- https://www.epa.gov/sites/default/files/2016-02/documents/tick-ipm-whitepaper.pdf

Preventative Technique Guides

Guidance when using Mosquito Dunks

- https://www.health.ny.gov/publications/13035.pdf

Tick Safety in Schools (Landscaping practices)

- https://www.epa.gov/sites/default/files/2014-11/documents/tick-safety-in-schools.pdf

Deer resistant plants and gardening

- https://www.canr.msu.edu/resources/smart_gardening_to_deter_deer
- https://www.canr.msu.edu/ipm/uploads/files/deer_resistant_plants.pdf

Supporting Ecosystem Services for Pest Management

Mosquitoes are most concentrated and accessible during their larval stage. Larval predation, like IPM larval control strategies, can help limit quantities of mosquitoes that reach adulthood. In Michigan, these predators include a variety of aquatic organisms such as dragonfly and damselfly nymphs, fish, amphibians, and turtles.

Because many of these organisms are vulnerable to habitat degradation, creating habitat is important for both their conservation and mosquito control. For example, Michigan is home to federally endangered species such as the Hine's Emerald Dragonfly. Likewise, salamanders and other amphibians are highly sensitive to aquatic pollution.

For households, supporting these species should revolve around water management and increasing habitat heterogeneity. Recommended approaches can vary based on landscape features.

- Homes with artificial ponds can:
  - Create habitat for dragonflies and damselflies.
  - Include mosquito-eating fish such as fathead minnows
  - Consider Bti treatments for additional mosquito management.

- Yards with water drainage problems can:
  - Install green stormwater infrastructure such as a rain garden to reduce standing water.

- Households can more generally:
  - Incorporate native plants to increase habitat heterogeneity and reduce need for chemical inputs.
  - Install artificial housing to provide habitat for pest-eating birds and bats.
  - Incorporate bird and bat-friendly gardening.

Convey broader synergies and homeowner benefits

When implemented properly, these strategies can both support mosquito control and provide other personal and environmental benefits. For example, rain gardens can help filter out pollution in runoff and reduce irrigation costs. These strategies can also add aesthetic value to a home and serve as engaging ways to build connect with gardening.

Emphasize the broader synergies and creative potential of these strategies when sharing materials with residents!

Provide external resources

There are ample guides available that provide information on how to implement many of these ideas. Beyond these baseline guides, share ways that residents can be creative and combine these strategies with their other household goals. Compile resources on guides for these topics and also share additional materials on how these strategies can be expanded in other ways.

ECOSYSTEM SERVICES FOR MOSQUITO MANAGEMENT

>>> SUPPORTING NATURAL PREDATORS

After female mosquitoes lay eggs in standing water, larvae hatch and leave the water as adults within 10-14 days. As adults, mosquitoes can disperse several miles away from breeding grounds. It is during their larval stage that they are most concentrated and immobile. In Michigan, healthy aquatic systems can include a variety of larval predators such as dragonfly and damselfly nymphs, aquatic beetles, fish, amphibians, and turtles. Additionally, many species of dragonflies, birds, and bats consume large quantities of pest insects and are known to include mosquitoes in their diets. None of these species will singlehandedly eliminate mosquitoes, but collectively their presence in and around ponds, wetlands, and other water bodies can help to limit the quantity of mosquitoes reaching adulthood.

Aquatic habitat degradation from pesticide and nutrient runoff threatens populations of many aquatic species in Michigan. Salamanders and other amphibians for example, are particularly sensitive due to the permeability of their skin. Some of these species, such as the Hine's Emerald Dragonfly, are listed as federally endangered.

Community support of habitat for native mosquito predators can both contribute to local resilience against mosquito abundance and help provide important conservation value for these at-risk species. At a household level, efforts to support natural predators of mosquitoes ultimately involve planning around water and creating habitat heterogeneity. Collectively, these efforts can act as an umbrella to support many other local species.

>>> ENHANCEMENTS TO ARTIFICIAL PONDS

Permanent fixtures of standing water, such as artificial ponds, can be breeding grounds for mosquitoes if stagnant. However, ponds can also provide needed habitat for wetland-dependent species. If you already have an artificial pond, or would like to create one, consider creating adjacent dragonfly habitat. Mosquito breeding in ponds can be limited by installing small waterfalls to keep the water moving. If ponds do not connect to other waterways, native fish such as fathead minnows can also be added to consume mosquito larvae. For a comprehensive guide, follow the QR code and review the linked guide to creating and maintaining dragonfly habitat.

>>> RAIN GARDENS

On the other hand, if you have a problem with rainwater collecting into standing pools, consider building a rain garden. Rain gardens help water from poorly drained areas infiltrate into the ground while also filtering pollutants that may instead run off into waterways. Rain gardens preferably utilize deep-rooted native plants, which can also provide habitat to mosquito predators and pollinators. For a guide to constructing a rain garden, follow the QR code.

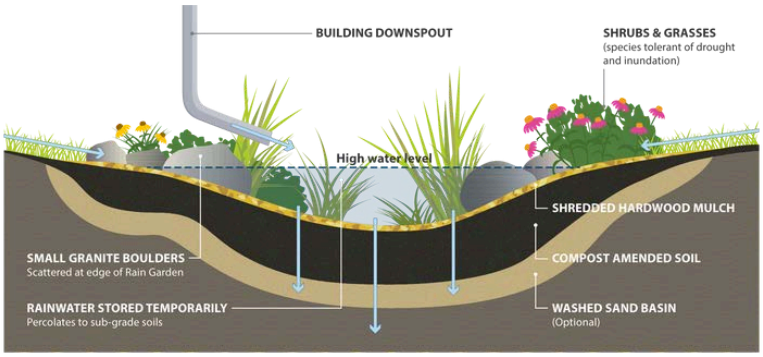


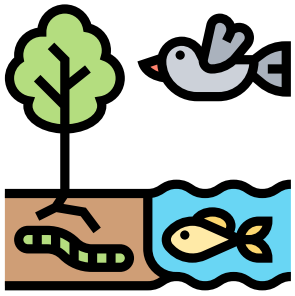
IMAGE SOURCE: HTTPS://TRCA.CA/NEWS/COMPLETE-GUIDE-BUILDING-MAINTAINING-RAIN-GARDEN/

HOW TO CHOOSE?

While water systems and habitat heterogeneity closely interact with natural mosquito management processes, their quality also drives other environmental benefits.

These benefits can include providing pollinator habitat, reducing need for pesticides and fertilizers, to preventing nonpoint source pollution loads from reaching waterways.

There are many small ways to make an impact so consider your interests and tailor these strategies to your goals - whether those are adding aesthetic value to your home or learning more about your local flora and fauna!



>>> HABITAT DIVERSIFICATION

Habitat heterogeneity is an important factor that can drive species richness in a landscape. Compared to plain lawns, mixtures of native plants and kinds of vegetation, can provide food and shelter for a more balanced variety of invertebrates, while also being more resilient to local pests and reducing the need for chemical treatments. Similarly, features such as trees in different phases of their growth and decay cycles can provide a variety of nesting and roosting options for birds and bats. Structures such as bird houses and bat boxes can also help increase roost habitat diversity.

THE CITY OF Kalamazoo

INSERT QR CODE HERE

ECOSYSTEM SERVICES FOR MOSQUITO MANAGEMENT

The following resources can be made available for residents on Kalamazoo's sustainability webpage, which can be linked in the QR codes.

Supporting Local Species

Michigan species:

- https://www.michigan.gov/dnr/education/michigan-species

Michigan Threatened and Endangered Species

- https://www.michigan.gov/dnr/managing-resources/wildlife/wildlife-permits/threatened-endangered-species/threatened-and-endangered-species-list

Prohibited species:

- https://www.michigan.gov/invasives/id-report/prohibitedrestricted

Strategies

Installing Green Stormwater Infrastructure: Rain Gardens

- https://www.ncei.noaa.gov/data/oceans/coris/library/NOAA/CRCP/other/other_crcp_publications/Watershed_USVI/stx_ee_hope_carton_road/130123_AttachmentC_11103.pdf
- https://trca.ca/news/complete-guide-building-maintaining-rain-garden/
- https://www.epa.gov/system/files/documents/2021-11/bmp-bioretention-rain-gardens.pdf
- https://www.epa.gov/system/files/documents/2021-10/raingardens_dec10_2slides.pdf
- https://xerces.org/blog/rain-gardens-are-winwin

Creating and Managing Habitat for Dragonflies and Damselflies

- https://xerces.org/sites/default/files/2018-05/14-010_01_Pond_Habitat_Guidelines_Odonates_Final_Websec.pdf

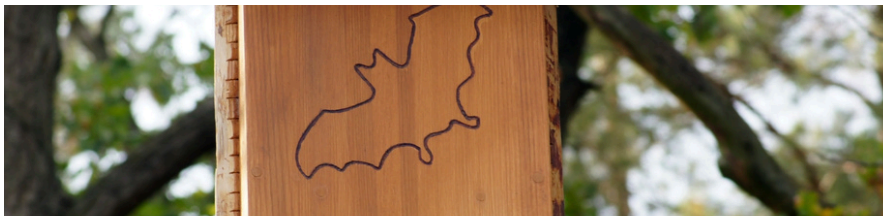
Native Garden Design's for Birds in Michigan

- https://www.michiganaudubon.org/wp-content/uploads/2018/03/Michigan-Native-Garden-Design-for-the-Birds.pdf

Bat-Friendly Gardening

- https://www.batcon.org/wp-content/uploads/2022/04/Guide-to-Gardening-for-Bats.pdf

Goals for Local Bat Conservation Programs



Importance of bat conservation in Michigan

While misconceptions surrounding bats are plentiful, the economic and ecosystem services that these flying mammals provide often goes understated. Estimates suggest that insect consumption by bats provides upwards of 3 billion dollars in savings for agricultural production annually in the United States. Individual bats can even consume quantities up to 3,000 insects in a single night. Bats are opportunistic feeders and do not necessarily target mosquitoes, but some species in Michigan, such as the little brown bat, are known to include mosquitoes in their diets. Through their guano, bats also help to cycle nutrients between aquatic and terrestrial systems. While all bats in Michigan are insectivorous, many frugivorous species in other parts of the world play important roles as pollinators and seed dispersers.

The species of bats known to occur in Michigan are:

- Little brown bat
- Big brown bat
- Indiana bat
- Silver-haired bat
- Red bat
- Northern long-eared bat
- Evening bat
- Hoary bat
- Tricolored bat

Unfortunately, bat populations have faced steep declines in Michigan due to a combination of habitat loss and an introduced fungal disease called White Nose Syndrome (WNS). The disease does not affect humans but it disrupts bats during their winter hibernation and causes them to use up their energy stores. Bats in affected hibernacula can have up to 90% mortality rates. Species such as the little brown bat that live in large colonies have suffered greatly as a result. Further, this issue makes bats even more vulnerable to habitat loss and other anthropogenic stressors. These factors make widespread habitat restoration and artificial roost construction important strategies to stabilize bat populations.

Bats are often misunderstood and coexistence strategies are not always well known. Accordingly, bat conservation can benefit from improving public awareness about issues facing bats, debunking misconceptions, and providing clear communications on how to safely respond to cases of human-bat interaction.

Studies on rabies transmission amongst bats in Central America suggest that rabies transmission is driven by infected individuals moving between colonies rather than individuals within colonies spreading it to one another. When bat colonies are culled or decline, this can facilitate drive increased movement between colonies and actually increase rabies transmission. Because many people fear bats, it is important to convey that while people should avoid contact with bats, the decline of the species does not remove zoonotic disease risk but rather changes the dynamics.

Community Programming

1. Public Education

As part of this IPM engagement strategy, awareness around the benefits bats provide and the risks they face within broader pest management systems can help residents see the connections between bats with their own well-being. Efforts should aim to reach both children and adults through fun, educational programming that explains the issues and provides hands on exposure to activities such as acoustic monitoring and bat box construction.

2. Habitat Restoration

At a city-wide scale, habitat suitability mapping can be used to prioritize habitat restoration efforts in areas currently suitable for bats. Individually, residents can participate in bat-friendly gardening. Further, partnering with local land conservancies can help coordinate restoration efforts in urban areas with existing initiatives. In Kalamazoo, one such organization is the Southwest Michigan Land Conservancy.

3. Artificial Roost Construction

Programming around bat box construction can help residents understand where and how bat boxes can most effectively be installed in their city. Increased placement of bat boxes collectively can provide bats ample roosting options allowing for coexistence with humans. It is important to communicate that bat boxes can remain unoccupied for many years. Availability of varied habitat provides optionality, so patience is key!

Bat Conservation Planning

1. Gauge Species Presence

Using available data (from sources like Midwest Bat Hub), gauge which species have been detected in the area. Knowing which species are currently present can elucidate whether bat box utilization is likely or whether other kinds of habitat restoration efforts may be more effective.

2. Public Engagement

Because bats are often misunderstood, public engagement in bat conservation programming should be accompanied by materials explaining why bat conservation and coexistence strategies can be beneficial to both people and the ecosystem. Some of the key concerns people have surrounding bats revolve around roosting in buildings and spread of rabies. Lack of high quality habitat drives bats to roost in undesired places. While bats do account for many rabies cases in the United States, rates of rabies in bat populations are low. Knowing how to identify and report potentially infected bats is a key part of avoiding rabies exposure. Clear communications on these topics can increase community understanding that coexistence strategies can help reduce unwanted interaction with bats while still receiving the ecosystem services that bats provide.

3. Habitat Suitability Mapping and Artificial Roost Site Selection

Using landscape-level criteria, evaluate bat habitat suitability in the focus area. Factors such as the presence of impervious surfaces, water bodies, and forests can help indicate where bats might have access to food and roost availability. Acquire representative remote sensing datasets and conduct a GIS-based suitability analysis to identify high quality habitat and places where artificial roosts placement may be most effective.

3. Acoustic Monitoring

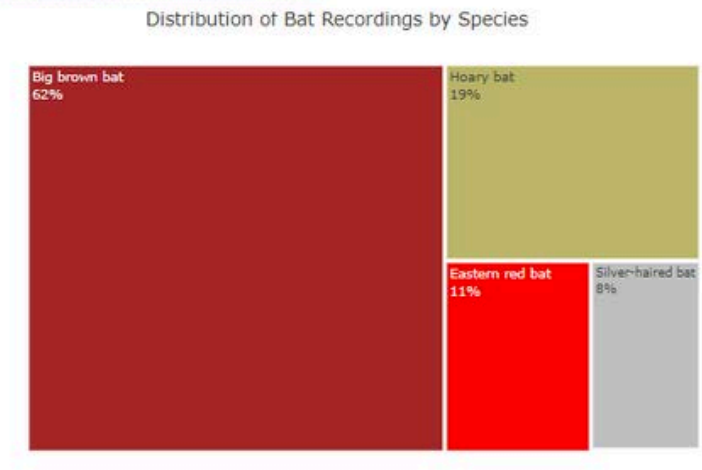
Using results from suitability mapping, it is recommended to conduct acoustic monitoring at priority sites. The results of these surveys can indicate the extent to which bat species are already present in the area. These findings can be used to further evaluate if the place is safe for bats. A full guidance document on how to conduct acoustic monitoring can be found here: https://www.nps.gov/subjects/bats/bat-acoustic-survey-guidance-and-database.htm

5. Install Artificial Roosts

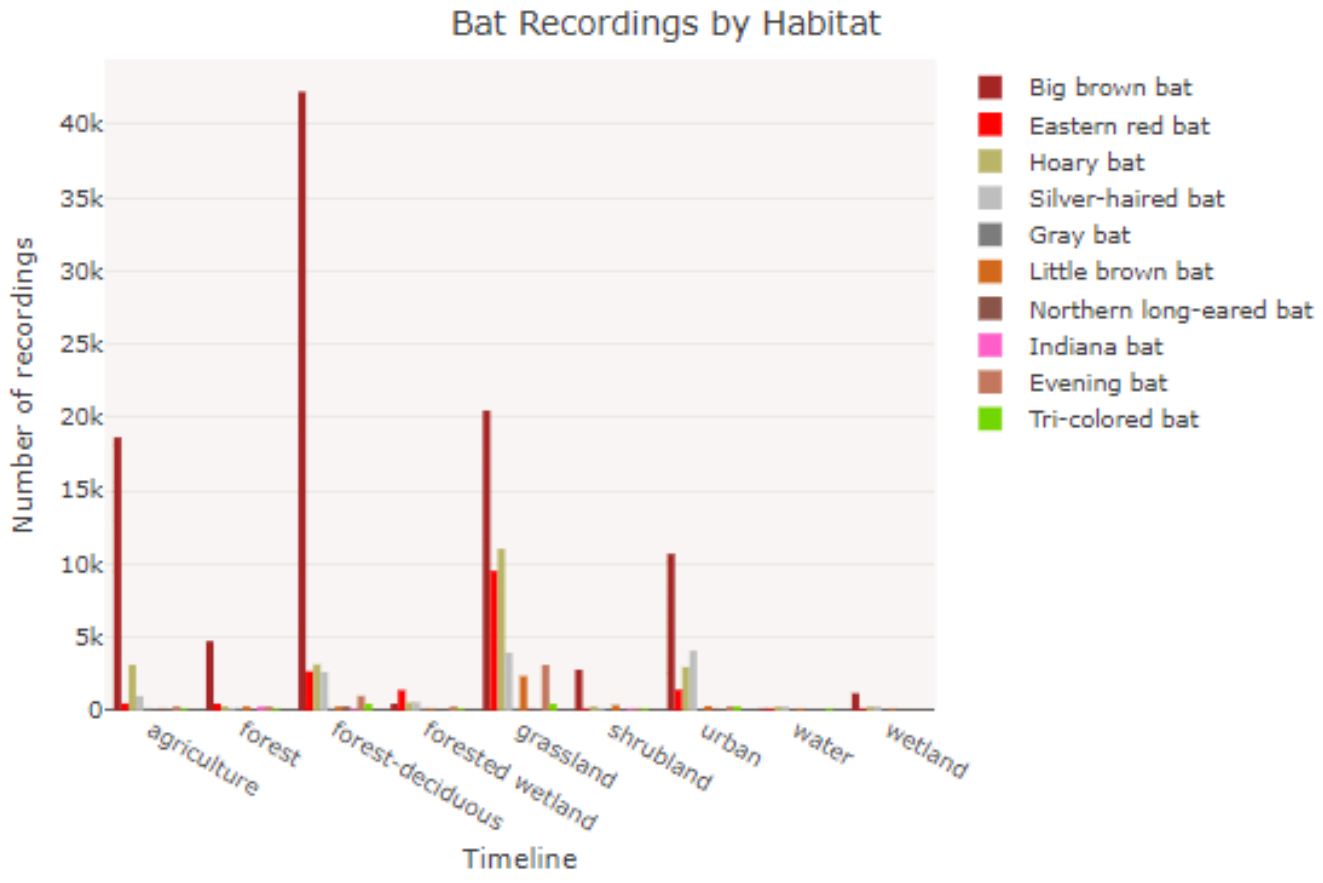
Finally, habitat restoration and bat box installations should proceed according to the previous evaluations. Roost construction should utilize untreated wood and follow designs outlined by Bat Conservation International. Placement should consider factors such as direction of sun exposure, color, and mounting height. A full guide on constructing and installing bat boxes can be found at https://batweek.org/wp-content/uploads/2018/01/BHBuildersHdbk13_Online.pdf

Kalamazoo Bat Species Detections

Acoustic surveys can help to identify the predominant bat populations in an area. Shown here are results of 2023 monitoring data collected at sites near Kalamazoo and submitted to the Midwest Bat Hub (data courtesy of Beth Keith). The most common species detected were the Big Brown Bat, the Hoary Bat, the Eastern Red Bat, and the Silver-haired Bat. There were also a few detections of the Little Brown Bat.
Awareness of the species present can help guide conservation strategies. Colony roosting bats such as Big Brown Bats and Little Brown Bats are known to occupy bat boxes. Meanwhile, more solitary species that roost in foliage — such as the Eastern Red Bat, the Hoary Bat, and the — less consistently utilize bat boxes.

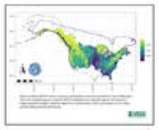


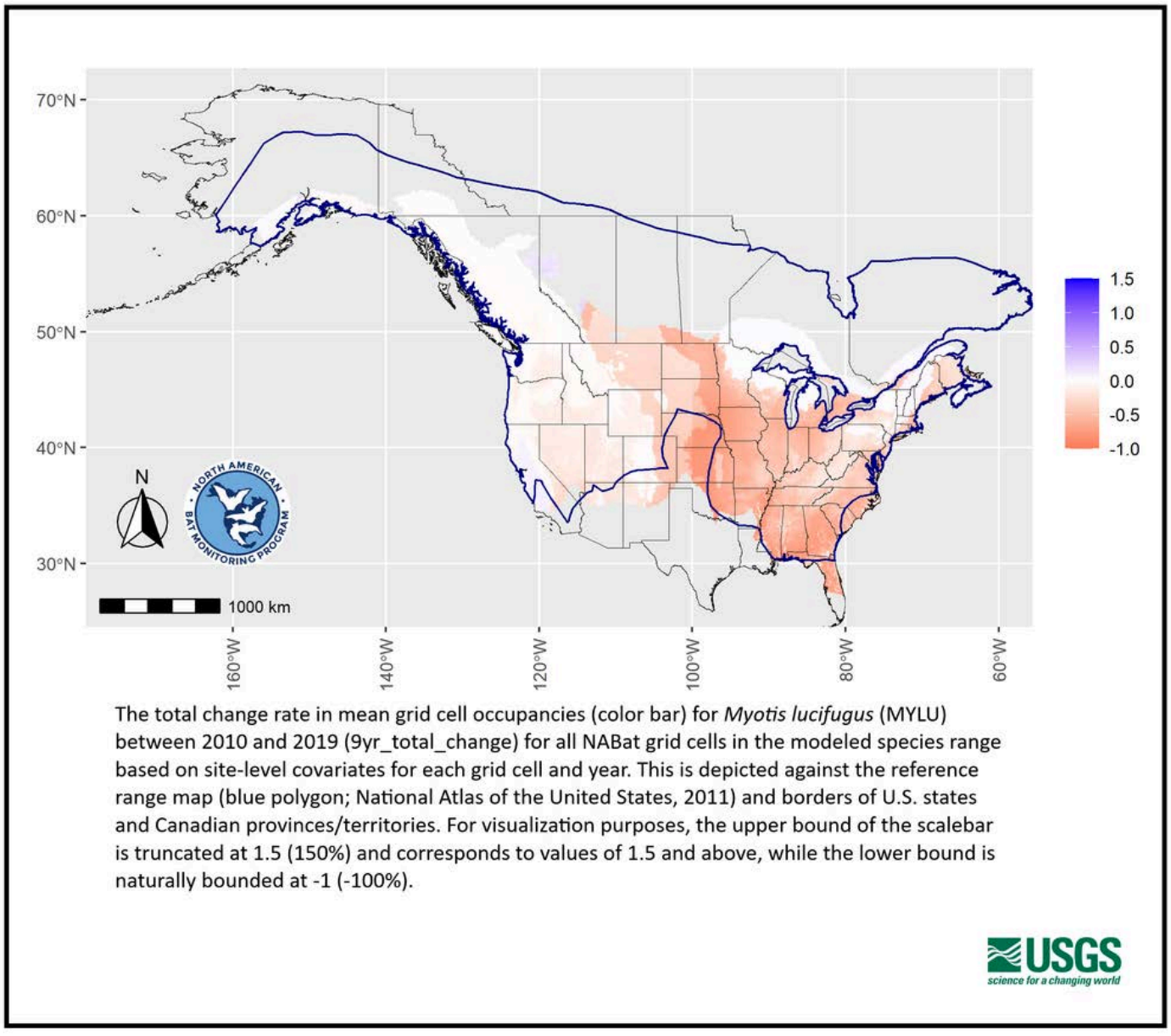
Detector	Site	Big brown bat	Eastern red bat	Hoary bat	Silver-haired bat	Gray bat	Little brown bat	Northern long-eared bat	Indiana bat	Evening bat	Tri-colored bat	Total bat calls
AB48	Carter Lake (SWMLC)	22	14	51	53	0	0	0	0	0	0	140
AB49	Armintrout-Millblocker (SWMLC)	376	754	366	76	0	6	0	0	0	0	1578
augusta	Augusta Floodplain (SWMLC)	237	14	343	87	0	0	0	0	0	0	681
blueberry	Mitchell's Patch of Blue Blueberry Farm	7	61	4	23	0	0	0	0	0	0	95
winterberry	Winterberry Woods (SWMLC)	771	17	165	184	0	2	0	0	0	2	1141
woodlawn	Woodlawn Preserve	3828	44	696	246	0	0	0	0	0	0	4814



Species In Decline: Little Brown Bats

Of the species detected in the 2023 acoustic monitoring, White Nose Syndrome has had a particularly devastating effect on Little Brown Bats. As seen here, their populations have experienced precipitous declines in Southwest Michigan since 2010. This species is the most well known mosquito predator of Michigan's bats. As they are not currently abundant in the Kalamazoo area, their story combined with their use of bat boxes can be used to illustrate why bats and artificial roost construction are important for local pest management and conservation programs.

Species	Status Variable	Latest Map	Total Change (2016-19)	Total Change (2012-19)	Total Change (2010-19)	Change Map
Little Brown Bat  *Myotis Lucifugus* State/Provincial Results	Summer Occupancy		-11.5% (CRI = -18.0% to -4.3%)	-19.8% (CRI = -27.2% to -11.7%)	-21.0% (CRI = -29.7% to -11.6%)	
	Summer Abundance	In Development	In Development	In Development	In Development	In Development
	Winter Abundance	In Development	In Development	In Development	In Development	In Development



The total change rate in mean grid cell occupancies (color bar) for *Myotis lucifugus* (MYLU) between 2010 and 2019 (9yr_total_change) for all NABat grid cells in the modeled species range based on site-level covariates for each grid cell and year. This is depicted against the reference range map (blue polygon; National Atlas of the United States, 2011) and borders of U.S. states and Canadian provinces/territories. For visualization purposes, the upper bound of the scalebar is truncated at 1.5 (150%) and corresponds to values of 1.5 and above, while the lower bound is naturally bounded at -1 (-100%).

Data from North American Bat Monitoring Program: https://sciencebase.usgs.gov/nabat/#/results

LOCAL BATS IN KALAMAZOO

Find more resources about bat safety and ways to effectively participate in bat conservation on our website:

INSERT QR CODE HERE

ABOUT OUR LOCAL BATS

Bats provide important pest management, pollination, and seed dispersal services across around the world. Estimates suggest that in the United States, insectivorous bats provide save the agricultural system over 3 billion dollars by reducing crop damage and pesticide applications!

Bat species in Michigan, all of which are insectivorous, include the following species:

- Big Brown Bat
- Hoary Bat
- Eastern Red Bat
- Silver-haired Bat
- Little Brown Bat
- Indiana Bat
- Northern Long-Eared Bat
- Evening Bat
- Tricolored Bat

Of the above, acoustic surveys from shared to the Midwest Bat Hub have identified the 5 underlined species (in order of detection quantity) at monitoring sites around Kalamazoo. While the Little Brown Bat is now rarely found around Kalamazoo, it is one of the primary species that includes mosquitoes in their diets.

POPULATION DECLINES

A variety of factors have led to steep population declines in bats across Michigan. White-Nose Syndrome (WNS) is a fungal disease that was introduced to the United States in recent decades. While it does not affect humans, the condition irritates bats during their hibernation, leading them to wake up and exhaust needed the energy stores they need to survive winter conditions. Species such as the little brown bat, that roost in social groups have been some of the most affected with up to 90% mortality rates in affected colonies.

Emerging threats such as WNS make bats particularly vulnerable to habitat loss and other pressures. Habitat restoration, preservation of corridors, and the provisioning of alternative roost (such as bat boxes) can help bat populations withstand these stressors.

COEXISTENCE AND MISCONCEPTIONS

There are many reasonable fears and misconceptions about bats, particularly around roosting in buildings and spread of rabies.

- Many bats naturally roost in tree cavities and other similar structures because they provide stable temperatures and protection from predators. Loss of natural roost options can drive bats to seek shelter in roofs and cellars that provide some of the same benefits. Taking preventative measures to seal openings in houses and installation of bat boxes can help reduce human exposure to bats.
  - If bats are found roosting in your home, exclude and relocate them humanely by calling a trained bat rehabilitator.

- While rabies rates amongst bats are low, medical care should be urgently sought for direct human contact with a bat. Recognizing the signs of an infected bats contact are key to avoiding exposure.
  - Bats that are unusually active during daylight, or are grounded may have rabies. Do not approach these animals and call animal control.
  - Providing alternative habitat again is key to reducing human-bat contact.

Taking proactive measures to bat-proof buildings and provide alternative habitat can help communities reduce health risk while benefiting from the ecosystem services that bats provide.

HOW TO HELP LOCAL BATS

Keep pet cats indoors. Cats can hunt bats using their night vision and ability to hear high frequency sounds made by bats.

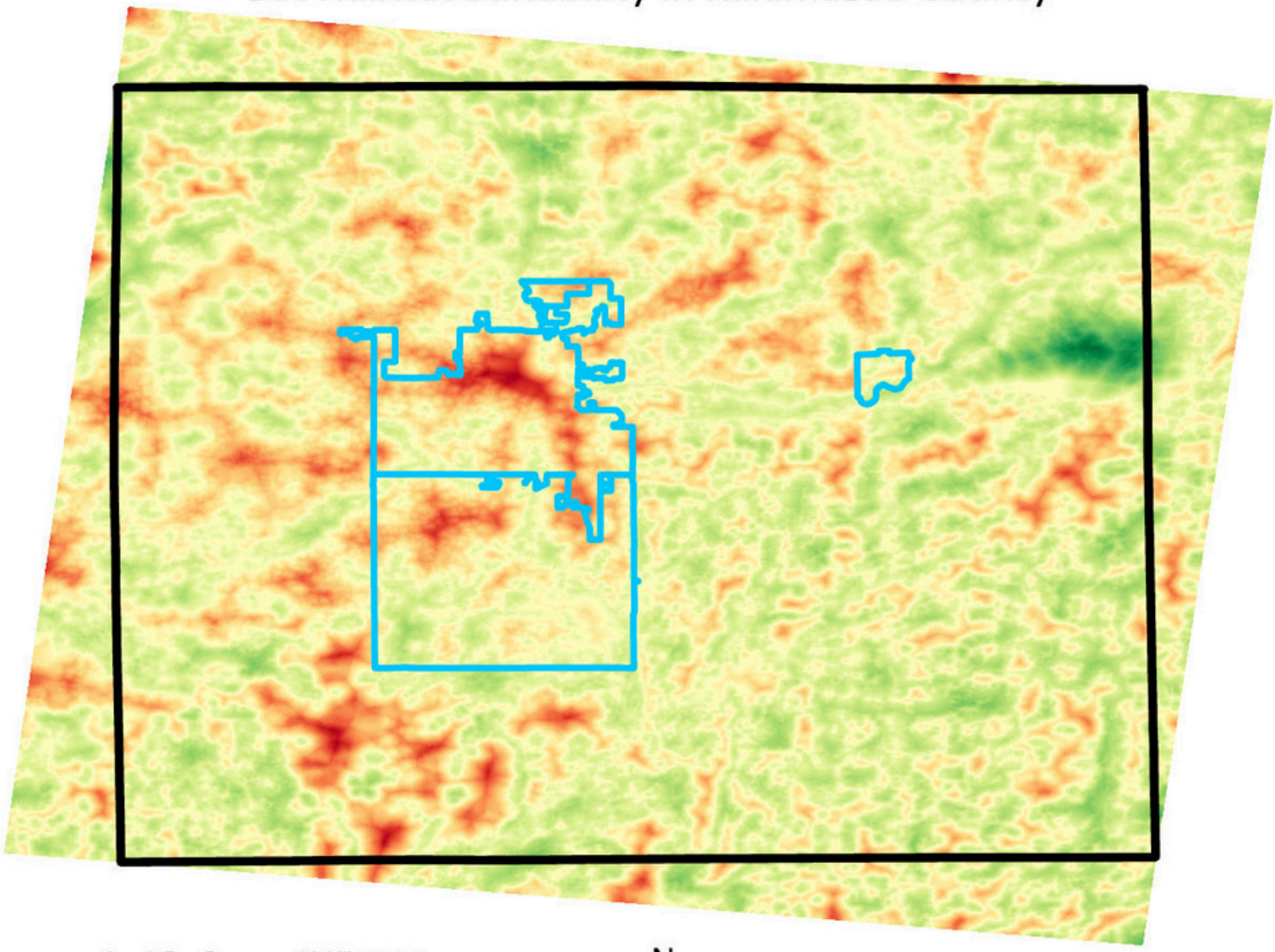
The bat box here is located on the University of Michigan's North Campus

Turn off outdoor lights. Lights can disturb how bats hunt and can limit their ability to catch night flying insects.

Install bat boxes. Join the City of Kalamazoo's efforts to improve habitat availability for bats. Make sure to follow our recommended guides regarding construction materials, placement, and maintenance. Also read carefully about including vents to reduce overheating risk.
It can take time, sometimes years, before bats move in. Observe and be patient!

Plant a bat-friendly garden! The presence of fragrant or light-colored flowers, native plants, and trees at different stages of their growth cycle can provide bats alternative habitat and food. These strategies can also support a variety of other native species.

Bat Habitat Suitability in Kalamazoo County



0 2.5 5 10 Kilometers

N

Kalamazoo County
Cities

Habitat Quality Score
2.98875
0.768439

Although each bat species in Michigan has specific habitat preferences, high quality bat habitat generally requires access to forests and water/wetlands. High quality bat habitat is also generally away from developed areas where impervious surfaces limit prey availability.

This map shows a calculation of bat habitat suitability across Kalamazoo County. The scores are derived from each location's distance away from intensely developed areas, proximity to water or wetlands, and proximity to dense tree canopy cover.

Areas with high habitat suitability can be evaluated using acoustic surveys to confirm whether bats are already present there. Suitability scores can also be used to inform where to plan conservation or ecological restoration efforts.

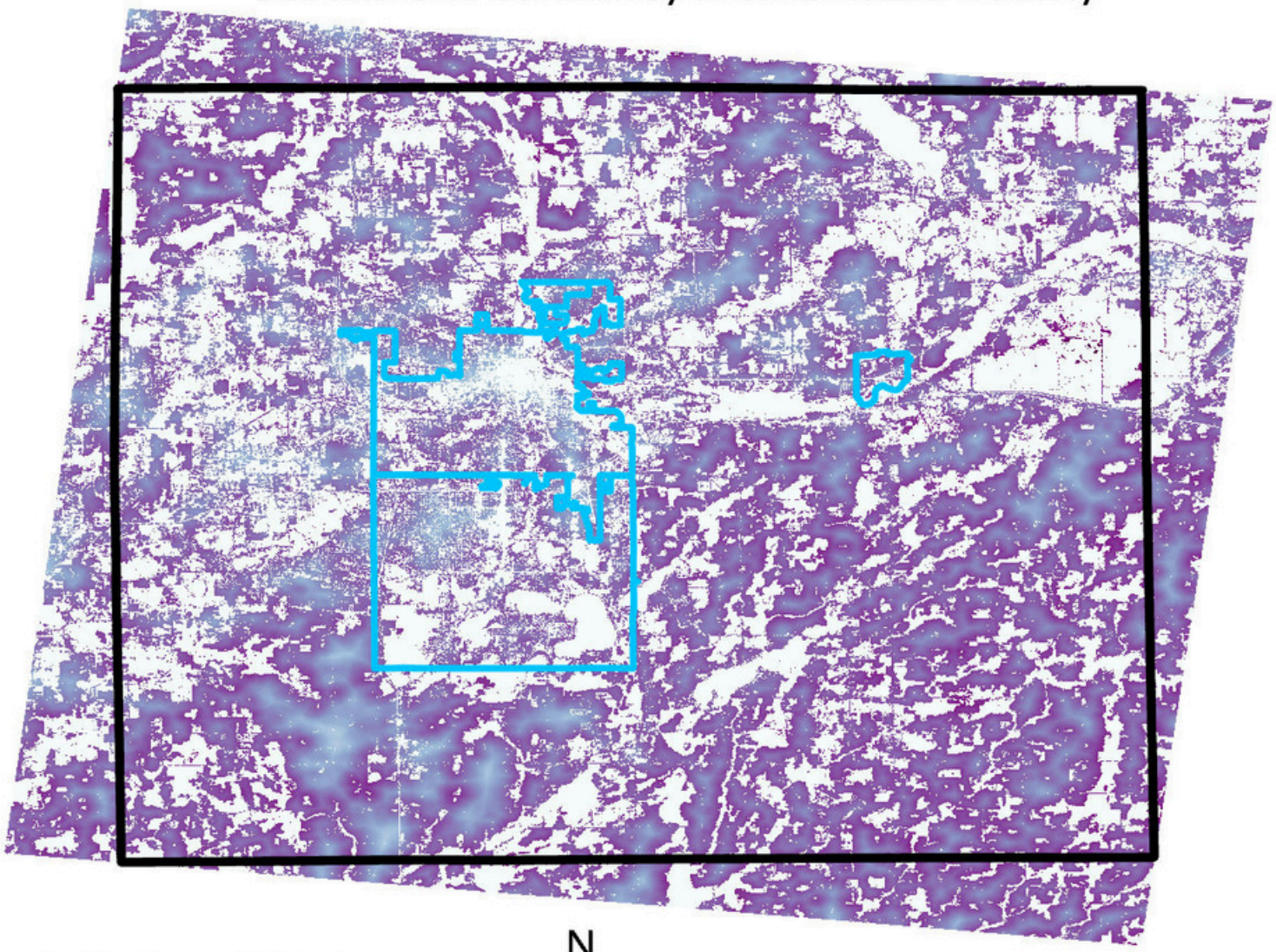
INSERT QR CODE HERE

THE CITY OF Kalamazoo

Data Sources:
Multi-Resolution Land Characteristics (MRLC) Consortium - [2021 CONUS Land Cover, 2021 CONUS Tree Canopy]
Data.gov - TIGER/Line Shapefile, 2023, County, Kalamazoo County, MI, Topological Faces (Polygons With All Geocodes)
Michigan GIS Open Data - Michigan Cities

Projected Coordinate System: Albers_Conical_Equal_Area
Datum: D North American 1983

Bat Box Site Suitability in Kalamazoo County



Although each bat species in Michigan has specific habitat preferences, high quality bat habitat generally requires access to forests and water/wetlands. High quality bat habitat is also generally away from developed areas where impervious surfaces limit prey availability. When deciding where to place bat boxes, factors about the feasibility of installation, maintenance, and likelihood of occupancy must considered. For example, bat box occupancy tends to be lower within forests because there is already natural habitat.

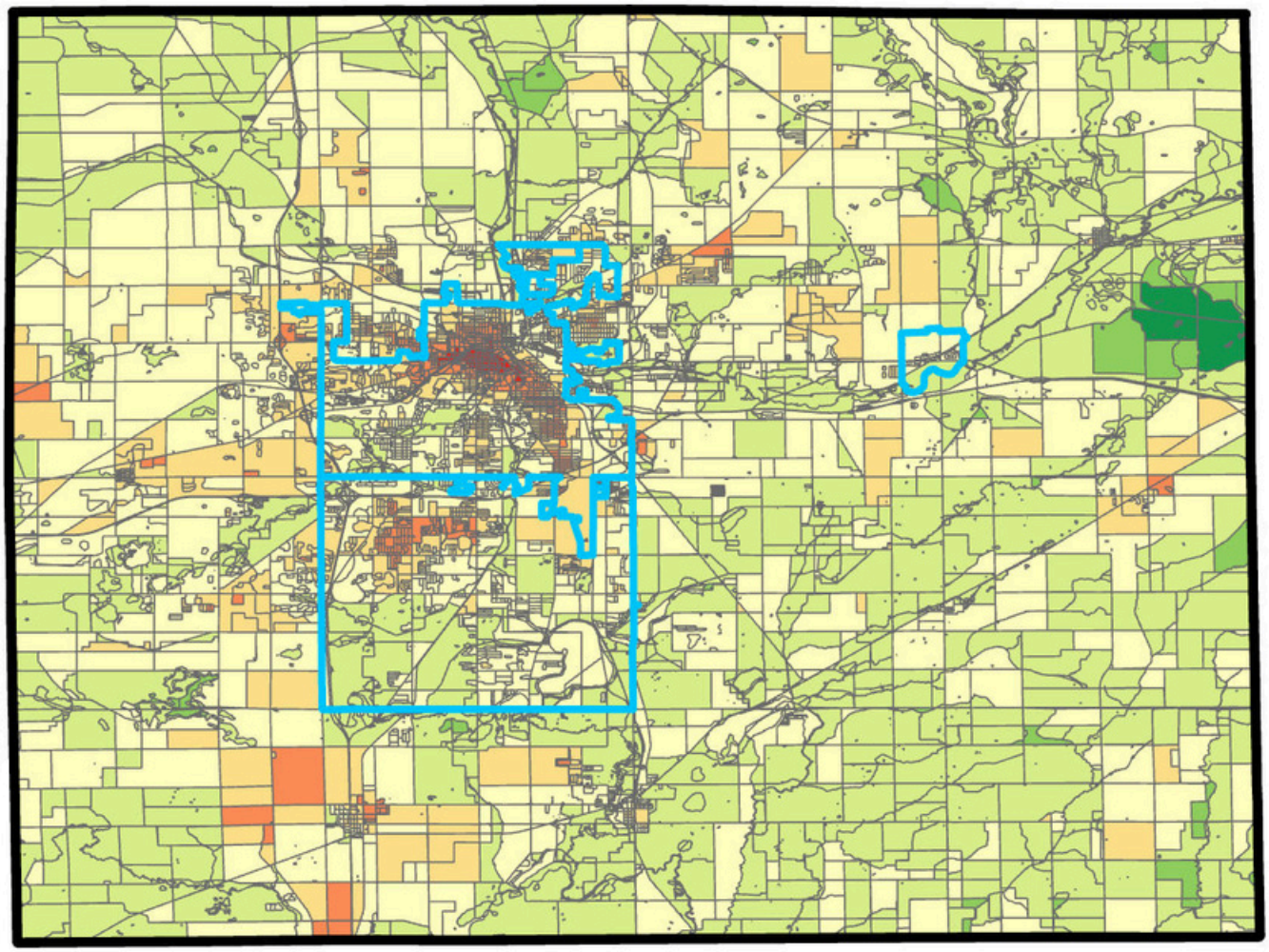
This map calculated bat habitat suitability across Kalamazoo County. Then the specific areas of water, dense forest, and intense development were given scores of 0 so that other areas can be prioritized for local bat box installation efforts. By prioritizing these other areas, bat boxes can supplement existing habitat while still striving for high occupancy.

THE CITY OF Kalamazoo

Data Sources:
Multi-Resolution Land Characteristics (MRLC) Consortium - [2021 CONUS Land Cover, 2021 CONUS Tree Canopy]
Data.gov - TIGER/Line Shapefile, 2023, County, Kalamazoo County, MI, Topological Faces (Polygons With All Geocodes)
Michigan GIS Open Data - Michigan Cities

Projected Coordinate System: Albers_Conical_Equal_Area
Datum: D North American 1983

Bat Habitat Quality in Kalamazoo County Census Tracts



0 2.5 5 10 Kilometers

N

CountyProjected
CitiesClipped

Mean Habitat Suitability Score

- 0.80 - 1.0
- 1.1 - 1.4
- 1.5 - 1.6
- 1.7 - 1.9
- 2.0 - 2.2
- 2.3 - 2.5
- 2.6 - 2.9

Did you know that areas close to water bodies and forests, and away from intense development can provide high quality habitat for bats. If you live in an area with a high habitat suitability score, there may be bats in your area! Always consider sealing gaps in your home to prevent bats from roosting in the wrong places. Further, consider helping out this important species through bat-friendly gardening, minimizing light pollution, and keeping cats indoors.

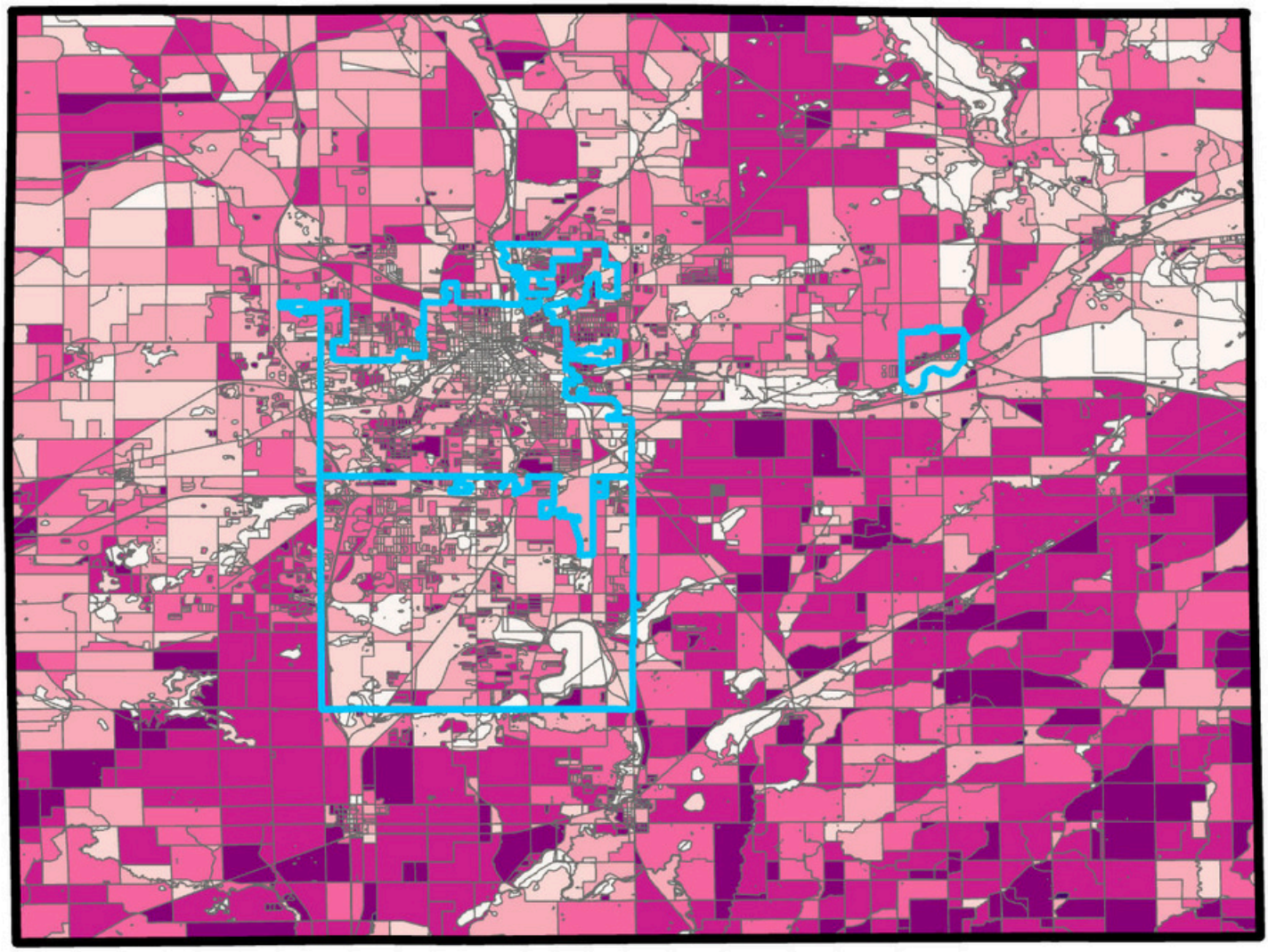
INSERT QR CODE HERE

THE CITY OF Kalamazoo

Data Sources:
Multi-Resolution Land Characteristics (MRLC) Consortium - [2021 CONUS Land Cover, 2021 CONUS Tree Canopy]
Data.gov - TIGER/Line Shapefile, 2023, County, Kalamazoo County, MI, Topological Faces (Polygons With All Geocodes)
Michigan GIS Open Data - Michigan Cities

Projected Coordinate System: Albers_Conical_Equal_Area
Datum: D North American 1983

Bat Box Site Suitability in Kalamazoo County Census Tracts



0 2.5 5 10 Kilometers

N

CountyProjected
CitiesClipped
Mean Bat Box Suitability Score
0.0 - 0.32
0.33 - 0.64
0.65 - 0.96
0.97 - 1.3
1.4 - 1.6
1.7 - 1.9
2.0 - 2.2

Check here to see if bat box installation might be an effective tool to support bats in your area. Habitat degradation is a driving factor for population declines for Michigan's bats. Bat boxes, can help address this issue by supplementing existing roost options. Placing bat boxes in priority areas can help optimize volunteer time and efforts, and likelihood of bats actually utilizing the structures.

INSERT QR CODE HERE

THE CITY OF Kalamazoo

Data Sources:
Multi-Resolution Land Characteristics (MRLC) Consortium - [2021 CONUS Land Cover, 2021 CONUS Tree Canopy]
Data.gov - TIGER/Line Shapefile, 2023, County, Kalamazoo County, MI, Topological Faces (Polygons With All Geocodes)
Michigan GIS Open Data - Michigan Cities

Projected Coordinate System: Albers_Conical_Equal_Area
Datum: D North American 1983

LOCAL BAT CONSERVATION

The following resources can be made available for residents on Kalamazoo's sustainability webpage, which can be linked in the QR codes.

Bat Information and Monitoring

Bats in Michigan

- https://www.canr.msu.edu/news/michigan-s-bats
- https://www.michigan.gov/dnr/education/michigan-species/mammals/bats
- https://www.fws.gov/sites/default/files/documents/Michigan%20Bat%20Project%20Review_April_12_2023.pdf

Ecosystem Services

- https://www.fws.gov/story/bats-are-one-most-important-misunderstood-animals

White Nose Syndrome

- https://www.biologicaldiversity.org/campaigns/bat_crisis_white-nose_syndrome/
- https://www.biologicaldiversity.org/campaigns/bat_crisis_white-nose_syndrome/Q_and_A
- https://www.whitenosesyndrome.org/static-page/bats-affected-by-wns
- https://wdfw.wa.gov/species-habitats/diseases/bat-white-nose

Bat population declines, WNS, habitat degradation

- https://www.biologicaldiversity.org/campaigns/bat_crisis_white-nose_syndrome/Q_and_A
- https://www.whitenosesyndrome.org/
- https://www.whitenosesyndrome.org/static-page/bats-affected-by-wns
- https://wdfw.wa.gov/species-habitats/diseases/bat-white-nose

Bat Monitoring Data

- https://midwestbathub.nres.illinois.edu/
- https://sciencebase.usgs.gov/nabat/#/explore
- https://sciencebase.usgs.gov/nabat/#/results

Guide for Acoustic Surveys

- https://www.nps.gov/subjects/bats/bat-acoustic-survey-guidance-and-database.htm

Edmonton, Canada: Example of another City Incorporating Bat Conservation into local IPM strategy

- https://www.edmonton.ca/programs_services/pests/edmontons-mosquito-control-program
- https://www.cbc.ca/news/canada/edmonton/bats-natural-pest-control-edmonton-1.6918681
- https://www.edmonton.ca/sites/default/files/public-files/assets/PoliciesDirectives/C501A.pdf?cb=1720027006

Support Bat Habitat

Bat-Friendly Gardening installation

- https://www.batcon.org/creating-a-garden-for-bats/
- https://www.batcon.org/wp-content/uploads/2022/04/Guide-to-Gardening-for-Bats.pdf

Bat box construction and installation guides

- https://batweek.org/wp-content/uploads/2018/01/BHBuildersHdbk13_Online.pdf

How Coexistence Strategies Can Help People and bats

How to bat-proof a house:

- https://www.farmanddairy.com/top-stories/how-to-keep-bats-out-of-your-house/403333.html

Understanding Rabies Transmission

- https://www.cdc.gov/rabies/prevention/bats.html

Humanely relocate bats from buildings (Find a local bat rehabilitator)

- https://batworld.org/local-rescue/
- https://www.dnr.state.mn.us/livingwith_wildlife/bats/exclusion.html
- https://www.batcon.org/about-bats/bats-in-homes-buildings/

How does biodiversity loss increase the spread of zoonotic disease?

- https://pubmed.ncbi.nlm.nih.gov/37272224/

Spread of rabies can increase when bat colonies are culled or decline

- https://www.nbcnews.com/sciencemain/why-killing-vampire-bats-wont-stop-spread-rabies-2d11687782
- https://news.umich.edu/culling-vampire-bats-to-stem-rabies-in-latin-america-can-backfire/

Spatial Planning For Bat Conservation Using Our Downloadable Suitability Models

As described earlier, setting up artificial bat roosts can first benefit from spatial planning to understand where the highest quality bat habitat is in the area. We have developed a tool using ArcGIS that project planners can use to create suitability maps for quality bat habitat and prioritized bat box installation sites. The following pages will explain how to download the model and apply it in any county in Michigan. This first tutorial will not go in depth into the underlying workings of the models, but will instead focus on running them to produce the results. To learn the configurations and how to further optimize the analysis, continue on to the second tutorial.

The outputs from these models can be used for planning purposes or for creating maps like those in the public-facing flyers on the previous pages.

Spatial Planning for Bat Conservation

Spatial planning goals for bat conservation

- Habitat - Identify existing areas that are high quality habitat for bats. Natural landscapes in these areas can be prioritized for bat-oriented conservation and ecological restoration.
- Bat Box Sites - Identify highest habitat quality areas where bat boxes can feasibly be placed and are likely to achieve occupancy.

Ideal landscape characteristics of quality habitat and bat box installation sites

- Habitat - Each bat species has different habitat requirements, but broadly Michigan's bats prefer to roost in areas with access to forest and permanent water bodies / wetlands. They also thrive better in areas away from concentrated urban development which may contain light pollution and impervious surfaces that limit prey availability.
- Bat Box Sites - Although forests provide necessary habitat for bats, occupancy of bat boxes within forests is low because they already contain diverse roost options. Similarly, bat box installation and maintenance is not practical directly within wetlands and water bodies due to the lack of access to stable soil for mounting. A goal of installing bat boxes is to supplement existing habitat, so installation should be prioritized at sites that are not directly within these features.

Methods: A tool you can download and use for your own analysis

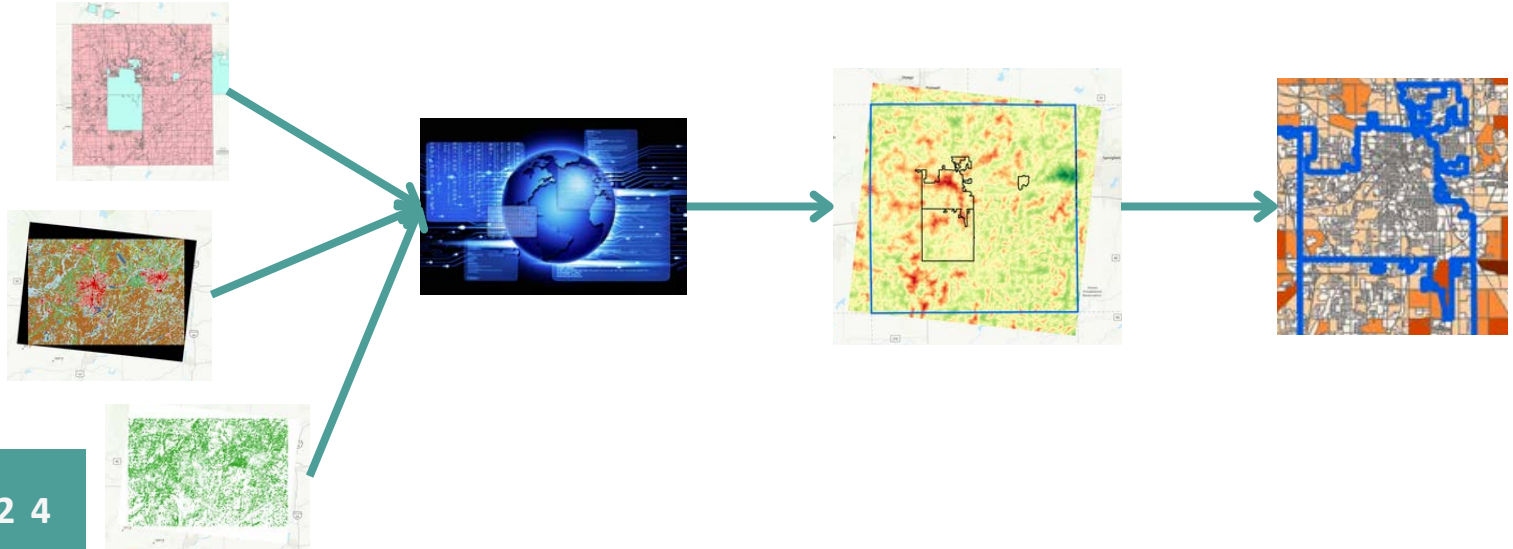
- We have created a Habitat Suitability Model for bats on ArcGIS Pro. This model accepts land cover feature data for a given county in Michigan. Then after running the model steps, it will create raster files indicating habitat suitability scores at locations across the county, which can then be used for planning.
- A ZIP file containing the ArcGIS project file with the model, the necessary file structure, and the data inputs and outputs associated with the Kalamazoo analysis is available as another deliverable on this project's page within https://graham.umich.edu/projects.
- The following pages will explain how to acquire the necessary data to provide to the model. They will also explain how the model was created and how to configure each step. The easiest way to use the model is to download the ZIP file and plug in your data. However, you can also use the guide to try and recreate it

Inputs:
- **County and City boundaries**
- **Land Cover data**

Tool:
- **ZIP file with ArcGIS models**

Outputs:
- **Habitat Suitability Maps**

Analysis:
- **Group data for local planning**



Using Our Suitability Tool

About the software

The tool we have created is an ArcGIS Pro project containing a series of models created using the software's "ModelBuilder" functionality. ModelBuilder allows all of the GIS procedures to be laid out in a sequential diagram. For this habitat suitability tool, this allows users to just add in a few county specific data layers at the beginning, press "run", and have all of the analysis steps done automatically. It also allows users to make changes within the suitability criteria and easily rerun the analysis without manually recreating each step.

If you are unfamiliar with ArcGIS Pro's ModelBuilder, consider visiting these tutorials from ESRI prior to using our tool:

- What is ModelBuilder?
  - https://pro.arcgis.com/en/pro-app/latest/help/analysis/geoprocessing/modelbuilder/what-is-modelbuilder-.htm
- Tutorial: Executing tools in ModelBuilder
  - https://desktop.arcgis.com/en/arcmap/latest/analyze/modelbuilder/executing-tools-in-modelbuilder-tutorial.htm
- Tutorial: Creating tools with ModelBuilder
  - https://desktop.arcgis.com/en/arcmap/latest/analyze/modelbuilder/creating-tool-with-modelbuilder-tutorial.htm

Data to download prior to using model

- Land Cover Classifications [From Multi-Resolution Land Characteristics Consortium]
- Tree Canopy Cover [From Multi-Resolution Land Characteristics Consortium]
- Land Parcels within the County [From Data.gov]
- Michigan City boundaries [From Michigan GIS Open Data]

Applying our bat habitat suitability model for your city

1. Select and download the spatial data Layers specific to your county
2. Download the "RoostSuitability" ZIP file containing the ArcGIS Project and unzip the file.
3. Move the county-specific spatial data into the project's "RawDataFiles" folder.
4. Update the variables in the first model to use the county-specific data.
5. Run the models in order.
6. Use the newly created suitability files for bat conservation planning.

What will the models within our tool do?

1. Reproject the spatial layers to a common coordinate system, and clip them to the County of focus.
2. Calculate distances from every point in the county to the closest landscape features of interest.
3. Convert these distances for each landscape feature into suitability scores from 0 to 1.
4. Combine the scores for each feature using a weighted sum to create a suitability map with combined scores for each pixel in the county.

- Values from the suitability maps can then be aggregated at different scales to help inform conservation planning.

The following pages will explain how to acquire the necessary data, and apply the model.

Acquire Data Sources

1

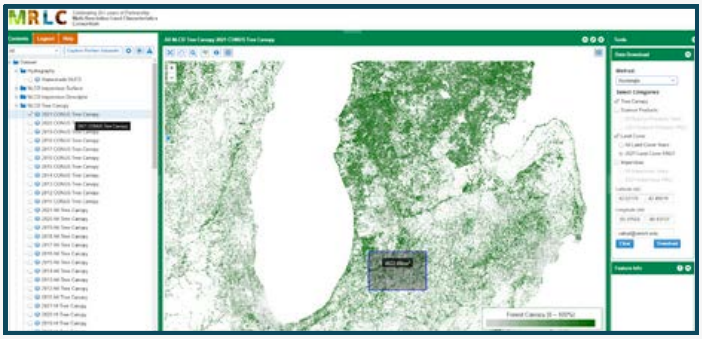
Bat habitat suitability analysis will be based on 3 landscape features:

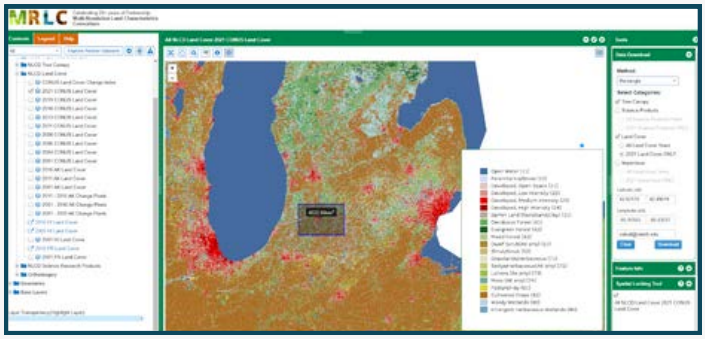
- Proximity to dense tree canopy cover
- Distance away from intense development
- Proximity to water sources and wetlands

All of these landscape features can be found from 2 Raster layers available from Multi-Resolution Land Characteristics Consortium (MRLC): https://www.mrlc.gov/viewer/

- Select the latest NLCD Tree Canopy layer: "2021 CONUS Tree Canopy" (by USGS National Land Cover Database)
- Also select the latest NLCD Land Cover: "2021 CONUS Land Cover" (by USGS National Land Cover Database)

Locate the County within which your analysis will be conducted and use the "Data Download" tool to draw a rectangle around the general region that encompasses the county's area. Submit the form and an email will be sent with a link to download a ZIP file containing the selected layers.





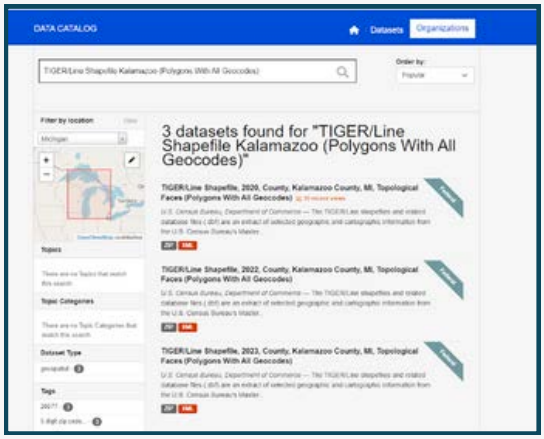
2

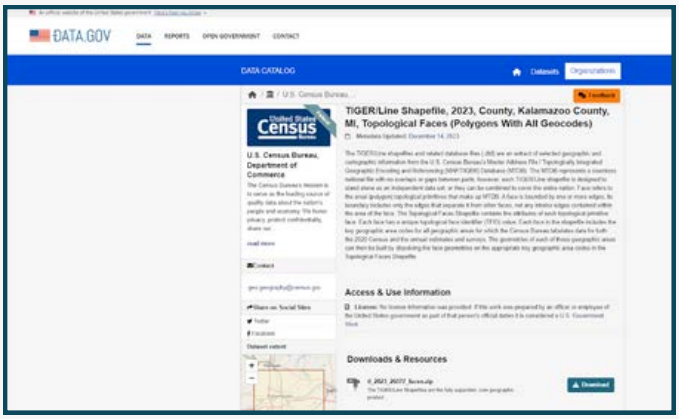
To focus the analysis on the local area, download a file with the land parcels of the county from Data.gov: https://catalog.data.gov/dataset

Find the appropriate shapefile by searching for "TIGER/Line Shapefile {County Name} (Polygons With All Geocodes)". Then select a file representing a recent year.
For this example we search "TIGER/Line Shapefile Kalamazoo (Polygons With All Geocodes)" and select "TIGER/Line Shapefile, 2023, County, Kalamazoo County, MI, Topological Faces (Polygons With All Geocodes)"

- https://catalog.data.gov/dataset/tiger-line-shapefile-2023-county-kalamazoo-county-mi-topological-faces-polygons-with-all-geocod

Download the ZIP containing the Shapefile.





3

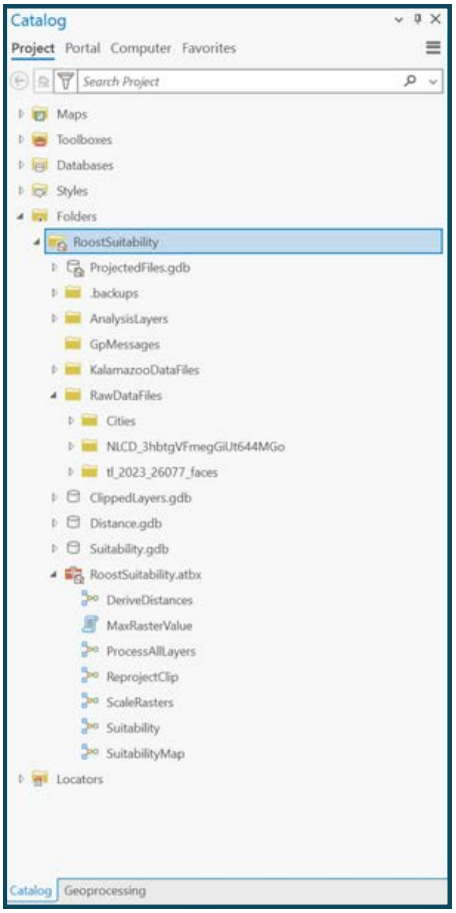
To overlay the cities within the county in the analysis, obtain the Michigan Cities from Michigan GIS Open Data: https://gis-michigan.opendata.arcgis.com/datasets/Michigan::cities-2/about
Click "View Map" to see the city boundaries and then download in Shapefile format.

Unzip the downloaded files. The contents will later be moved into the "RawRasterData" folder of the ArcGIS project.

Download and Run the Models

Download the models and opin in ArcGIS

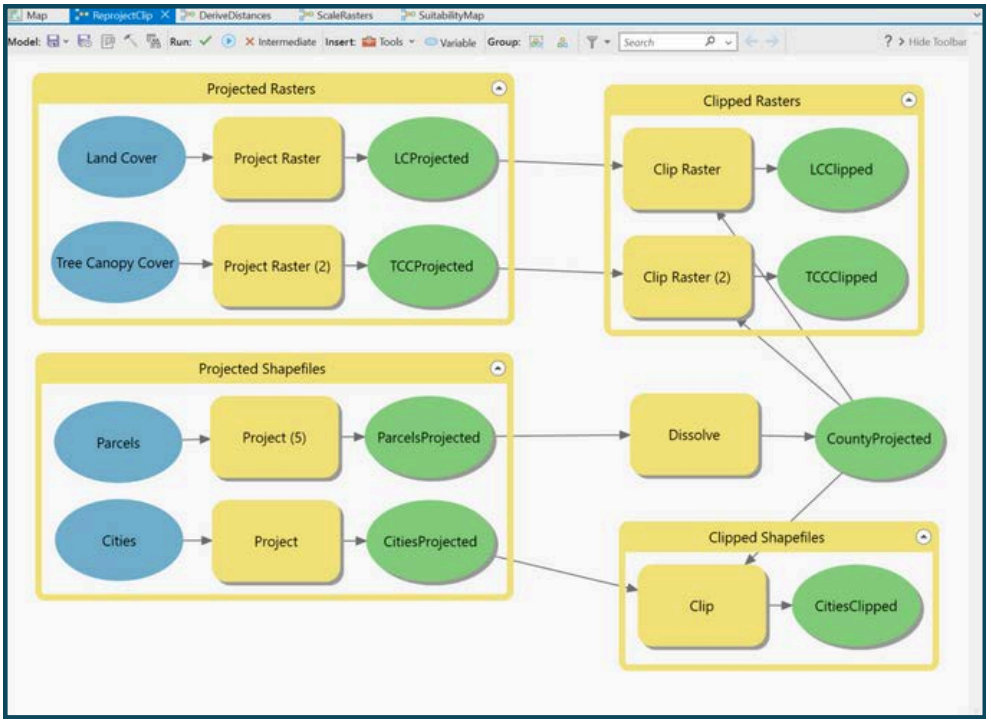
1. The model is available for download at https://graham.umich.edu/projects on this project's page. Download the ZIP file and unzip it in your file system.
2. Move the previously downloaded county-specific data layers into the project's "RawDataFiles" folder.
3. Open the ArcGIS Project File ("RoostSuitability.aprx")
    - Note that the Catalog Pane should resemble the the image.
        - There should be 4 geodatabases. Over the course of your analysis, computed files will be stored in these geodatabases.
            - ProjectedFiles.gdb
            - ClippedLayers.gdb
            - Distance.gdb
            - Suitability.gdb
        - Within the toolbox, ("RoostSuitability.atbx") there are also 4 models that will be run in the following order to perform the analysis:
            1. ReprojectClip
            2. DeriveDistances
            3. ScaleRasters
            4. SuitabilityMap



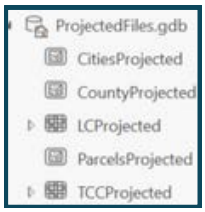
Run Model 1: ReprojectClip

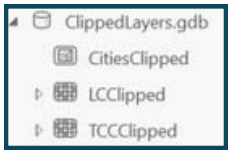
This model is the only one that requires configuration because the input data needs to be added.

- Edit each of the blue variables in this model so that the source file refers to the corresponding data in your "RawDataFiles" folder.



Then Run the model. It will reproject all of the data layers and select only the data located within the county boundary. Refresh the geodatabases and see the computed files now created. These will be used in the following models.



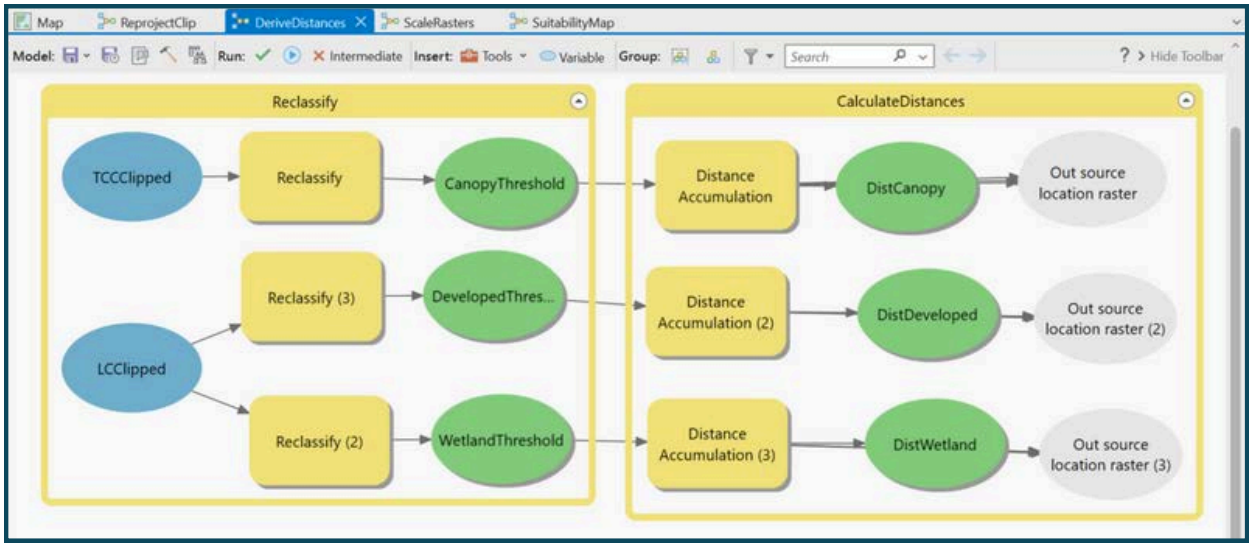


Download and Run the Models (Continued)

Run Model 2: DeriveDistances

No more configuration is required for the upcoming models. Run the model. It will create rasters representing the distance from each pixel to the closest of the three landscape features (dense forest, intense development, and water/wetlands).

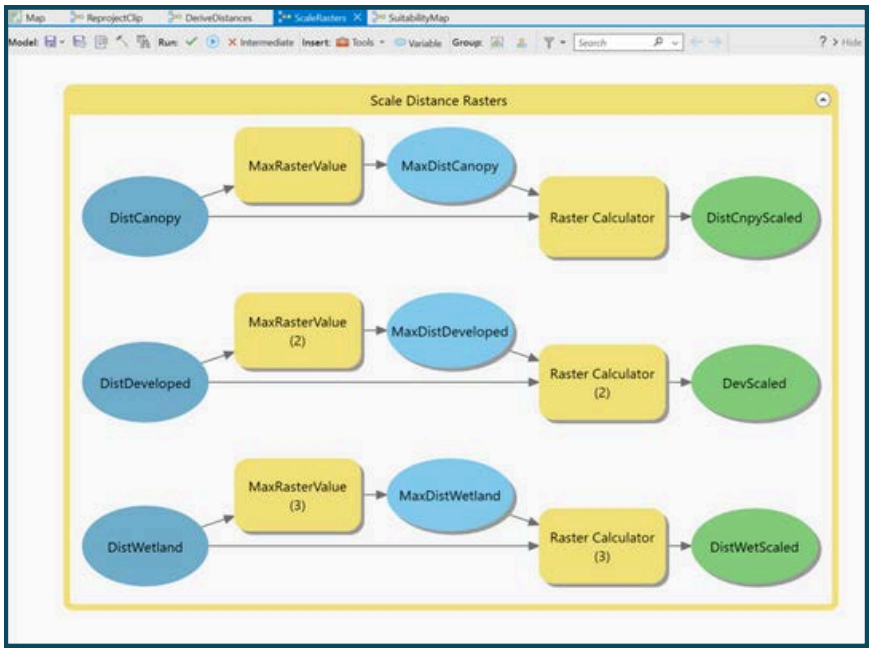
Refresh the geodatabases and see the computed files now created. These will be used in the next model.

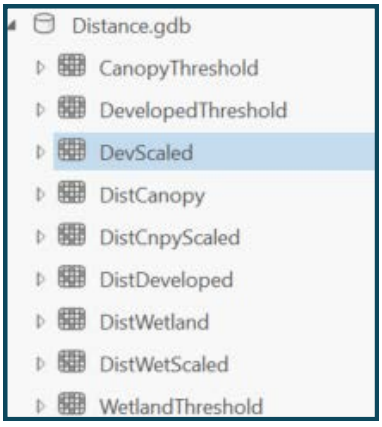


Run Model 3: ScaleRasters

Run the model. It will transform the distance rasters into scaled scores from 0 to 1 representing a suitability score based on that feature.

Refresh the geodatabases and see the computed files now created. These will be used in the next models.



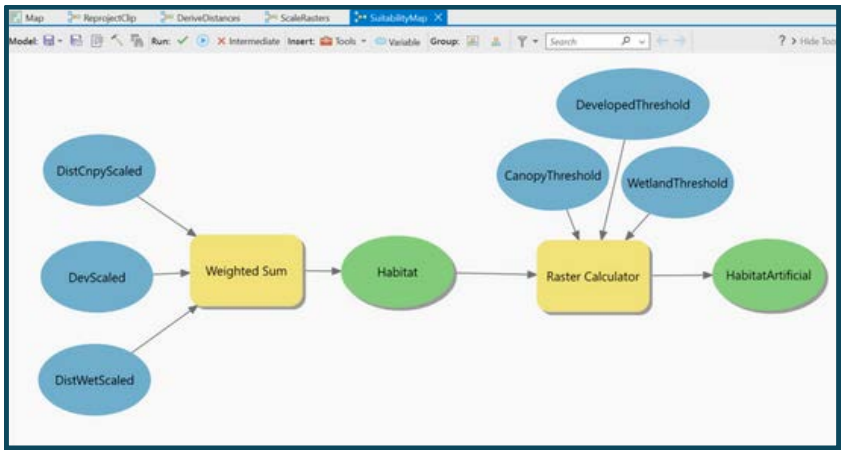


Download and Run the Models (Continued)

Run Model 4: SuitabilityMap

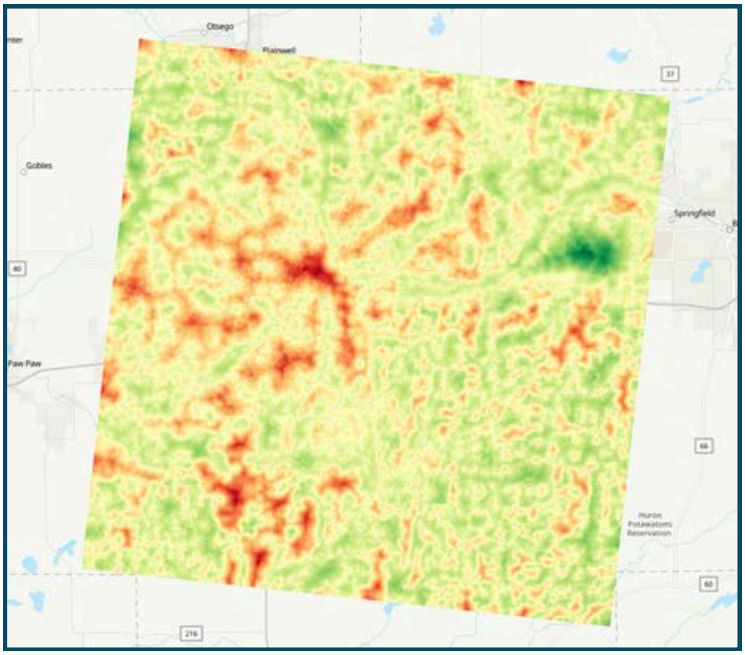
Run the model. It will compute a weighted sum and create the result rasters:

- “Habitat” - raster where values are scores for bat habitat suitability
- “HabitatArtificial” - raster where values are scores for places where bat boxes installation can be pursued according to our prioritization guidelines.

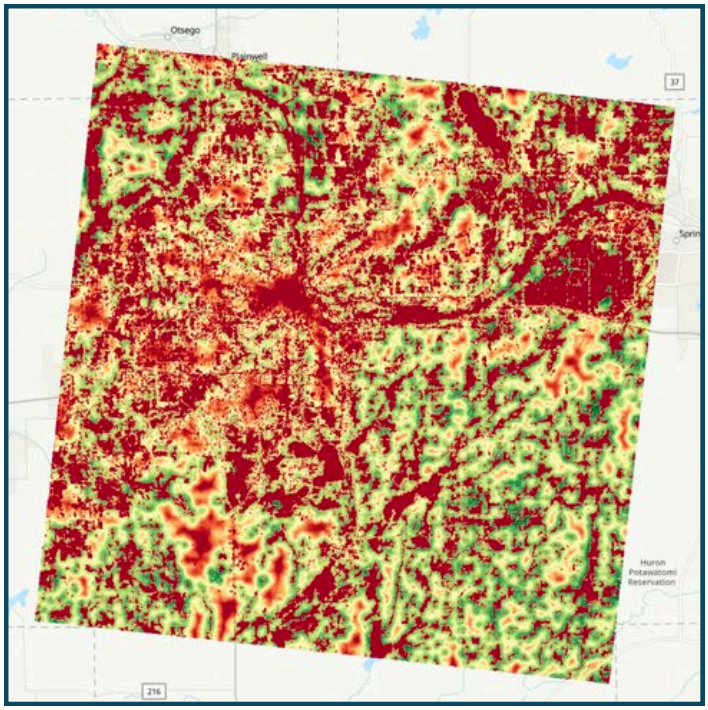


Refresh the geodatabases and see the computed files now created. These final files can be utilized for map making and further analysis.

Habitat



HabitatArtificial



Creating and Configuring the Models

As seen in the previous pages, downloading our model and producing the output maps can be done in just a few simple steps.

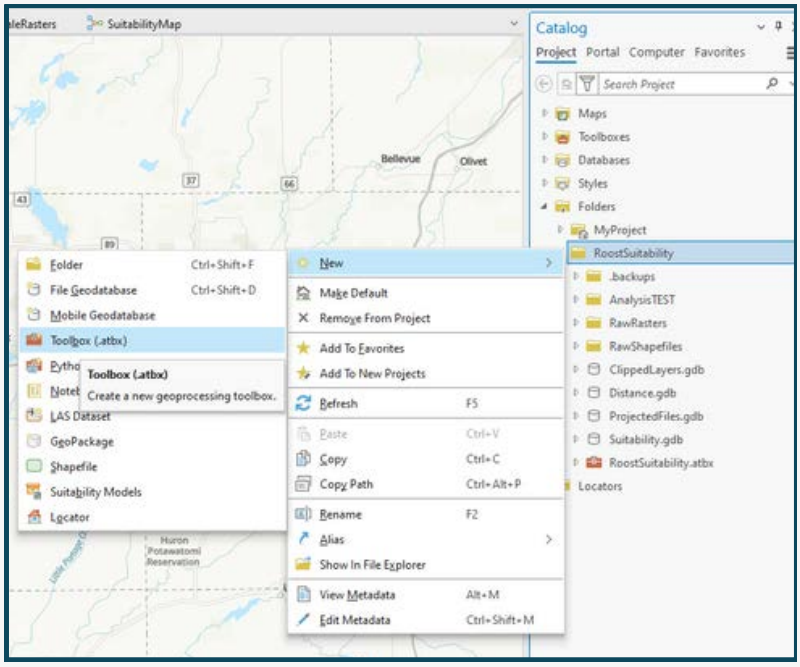
If however, a city's analyst may want to incorporate additional or different factors into their model. To do so requires a more in depth understanding of how each of the models components have been configured.

The following pages provide a more thorough walk through of the creation of each component for those who would would like to know the underlying mechanisms driving the analysis. The steps in the following pages will be particularly useful in illustrating how to add or modify steps within the models.

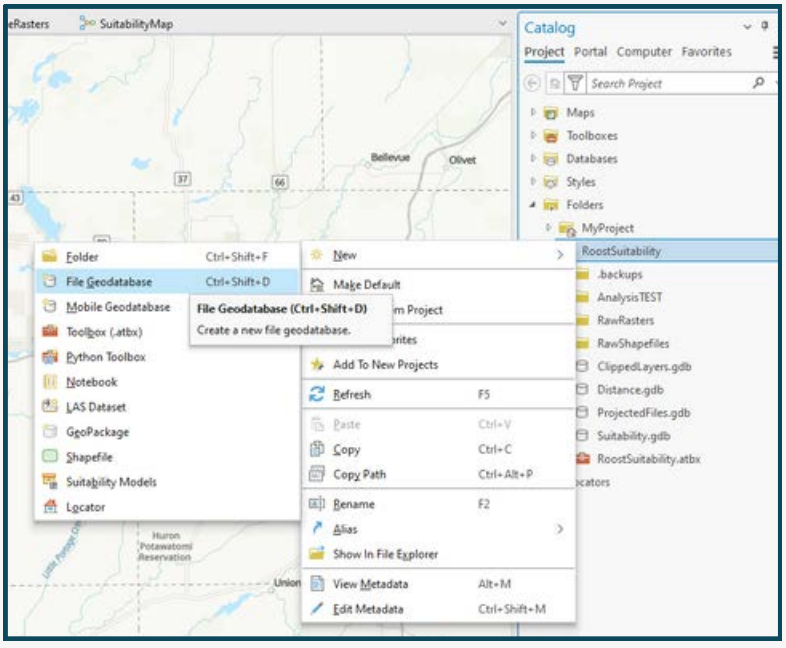
Setup ArcGIS Project

1. Create a new ArcGIS project using the default Map template and name it “RoostSuitability”

2. In the Catalog Pane, right click on the project folder and create a new “Toolbox (.atbx)”. Model builder files will be stored in the toolbox. Name it “RoostSuitability.atbx”.



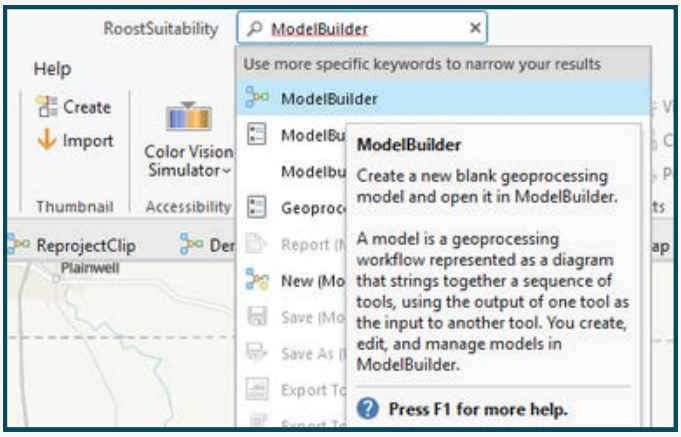
3. The analysis will have several stages (Data Projection, Clip to focus area, Derive Distance Rasters, and Final Suitability Maps) in which intermediate and final spatial layer files will be created. Geodatabases can help with storage and retrieval efficiency. Within the project folder create geodatabases to store files at each of these steps with the following names:
   1. “ProjectedFiles.gdb” (stores re-projected data layers)
   2. “ClippedLayers.gdb” (stores re-projected layers clipped to focal county)
   3. “Distance.gdb” (stores raster layers showing distance from habitat characteristics)
   4. “Suitability.gdb” (stores final suitability maps)



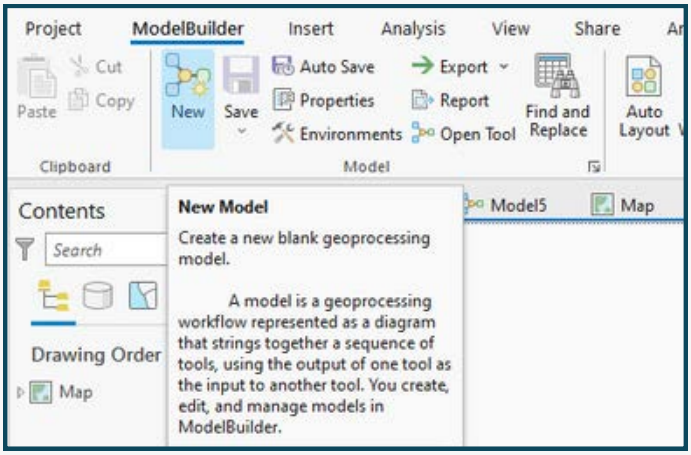
Create Empty Models

Create the empty models for each stage of analysis. These models will be stored within the ArcGIS Toolbox and updated later in the tutorial.

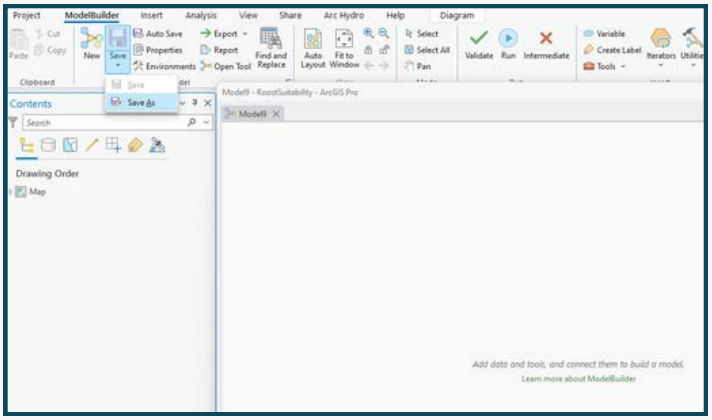
1 Search “ModelBuilder” in the search bar. This will open the ModelBuilder ribbon.



2 In the ModelBuilder ribbon, select “New” to create an empty model.



3 In the ModelBuilder ribbon, select “save as” and store this empty model within the “RoostSuitability.atbx” toolbox. Name the models using the list provided in step 4.

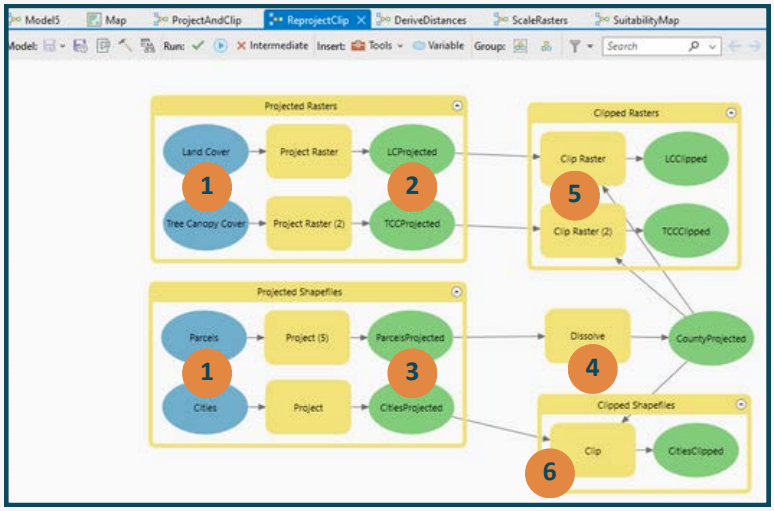


4 Repeat steps 2 and 3 in order to create a total of four models. In step 3, use the following names when saving each model:

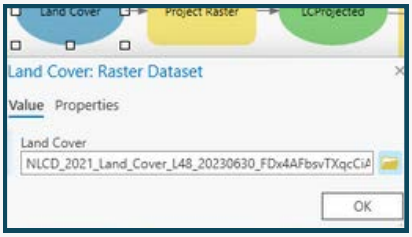
- ReprojectClip
- DeriveDistances
- ScaleRasters
- SuitabilityMap

Model 1: Reproject and Clip Layers

- **The spatial data layers acquired online have been created using different Projected Coordinate Systems (PCS). Analysis is more consistent when all data layers are reprojected to a common PCS.**
- **In this tutorial, all layers will be reprojected to match that of the Land Cover layer, which is "Albers_Conical_Equal_Area".**
- **The reprojected layers will then be clipped to remove data outside of the county limits, to focus the analysis on the target area.**
- **These steps describe how to configure each component of the diagram to the right.**
- **Tip: Use the "Group" tool to organize the components as shown.**



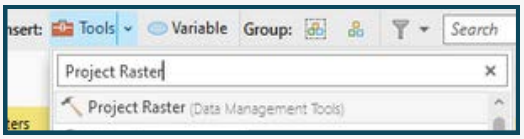
1 Open the empty "ReprojectClip" model.
Using the "Variable" button in the toolbar, create 4 variables (blue). Load each of the spatial layers previously downloaded and stored within the "RawDataFiles" folder. Since the file names may be long, right click on the variables and use "rename" to provide intuitive names: "Land Cover", "Tree Canopy Cover", "Parcels", and "Cities".

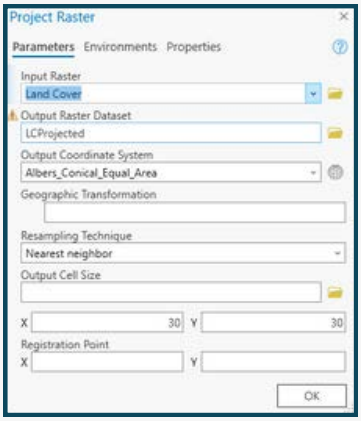


2 Each of the two raster layers ("Land Cover" and "Tree Canopy Cover") will be reprojected using the "Project Raster" tool.
Search for this tool in the "Tools" dropdown, and add it to the model. Open the component and configure the following parameters:

- Input Raster:
  - Scroll down to model variables and select "Land Cover".
- Output Raster Dataset:
  - Save as "LCProjected" within the "ProjectedFiles.gdb" geodatabase.
- Output Coordinate System:
  - Enter "Albers_Conical_Equal_Area", which will be the common PCS.

Repeat these steps to create another component that uses "Tree Canopy Cover" as the Input Raster and saves the output as "TCCProjected" within the same geodatabase.

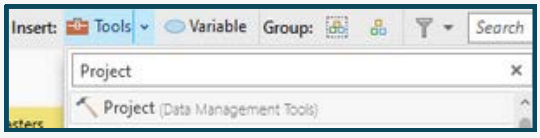


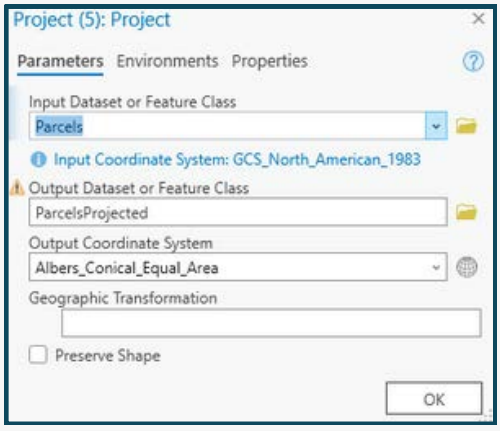


3 Each of the two vector layers ("Parcels" and "Cities") will be reprojected using the "Project" tool.
Search for this tool in the "Tools" dropdown, and add it to the model. Open the component and configure the following parameters:

- Input Dataset or Feature Class:
  - Scroll down to model variables and select "Parcels"
- Output Raster Dataset:
  - Save as "ParcelsProjected" within the "ProjectedFiles.gdb" geodatabase.
- Output Coordinate System:
  - Enter "Albers_Conical_Equal_Area", which will be the common PCS.

Repeat these steps to create another component that uses "Cities" as the Input Dataset and saves the output as "CitiesProjected" within the same geodatabase.

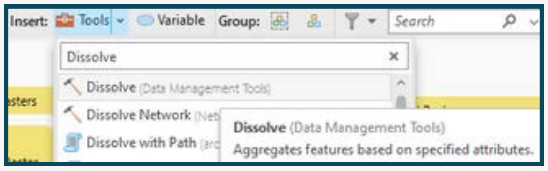


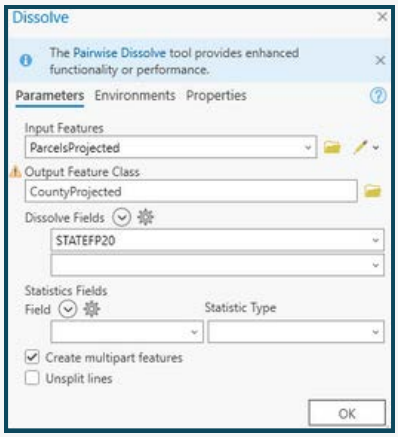


Model 1: Reproject and Clip (Continued)

4 Since the Parcels data divides the county into all of the land parcels, the combination of all of them represents the county area. Use the dissolve tool to derive the county boundaries.

- Input Features:
  - Scroll down to model variables and select “ParcelsProjected”
- Output Feature Class:
  - Save as “CountyProjected” within “ProjectedFiles.gdb”
- Dissolve Fields:
  - Select “STATEFP20” (Every parcel polygon is in the same state (Michigan), so they will all be dissolved together).

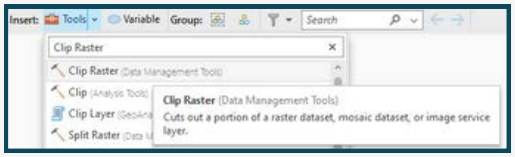


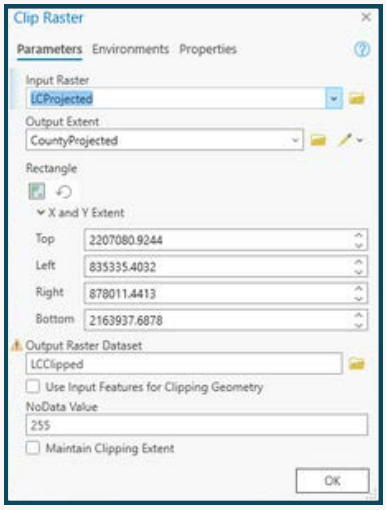


5 Now keep only the raster data within the focal area by clipping the raster layers with the county boundary using the “Clip Raster” tool.
Search for this tool in the “Tools” dropdown, and add it to the model. Open the component and configure the following parameters:

- Input Raster:
  - Scroll down to model variables and select “LCProjected”.
- Output Extent:
  - Select “CountyProjected” from the model variables in the dropdown.
- Output Raster Dataset:
  - Save as “LCCClipped” within the “ClippedLayers.gdb” geodatabase.

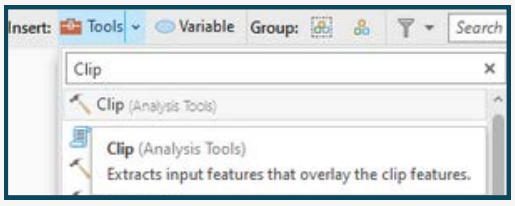
Repeat these steps to create another component that uses “TCCProjected” as the Input Dataset and saves the output as “TCCClipped” within the same geodatabase.

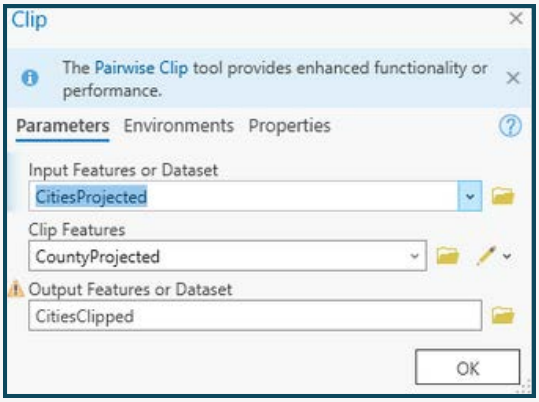




6 Now keep only the vector data within the focal area by clipping the vector layers with the county boundary using the “Clip” tool.
Search for this tool in the “Tools” dropdown, and add it to the model. Open the component and configure the following parameters:

- Input Features or Dataset:
  - Scroll down to model variables and select “CitiesProjected”.
- Clip Features:
  - Select “CountyProjected” from the model variables in the dropdown.
- Output Features or Dataset:
  - Save as “CitiesClipped” within the “ClippedLayers.gdb” geodatabase.





Model 1: Reproject and Clip (Outputs)

Click the Run button to execute the ReprojectClip model. Of the layers created, here are the ones that will continue to be used as the analysis progresses:

1 Reprojected raw data layers (within ProjectedFiles.gdb)

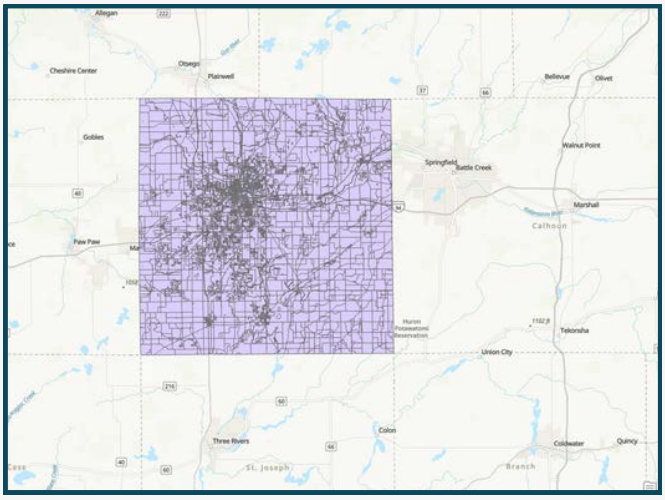
- CountyProjected - will be used as boundary for analysis and as border for maps
- ParcelsProjected - will be used to summarize suitability results at a land parcel level

2 Layers clipped within county boundary (within ClippedLayers.gdb)

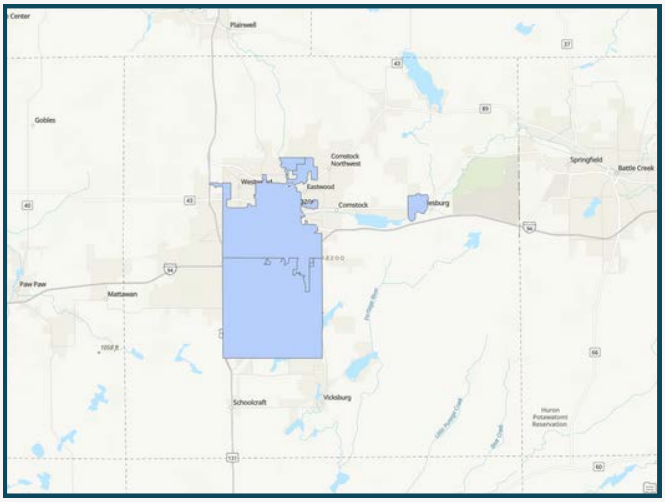
- CitiesClipped - county-level city boundaries that will be used to outline cities in maps
- LCClipped - county-level land cover data that will be used to identify intensely developed land and wetlands.
- TCCClipped - county-level tree canopy data that will be used to identify areas with high percentage canopy cover

CountyProjected

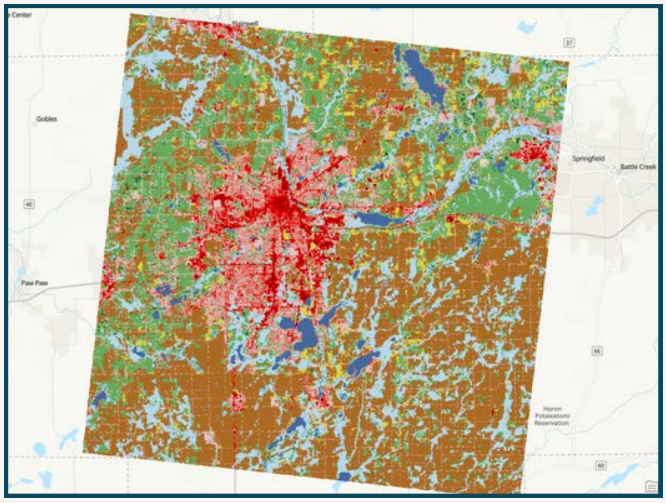
ParcelsProjected



CitiesClipped



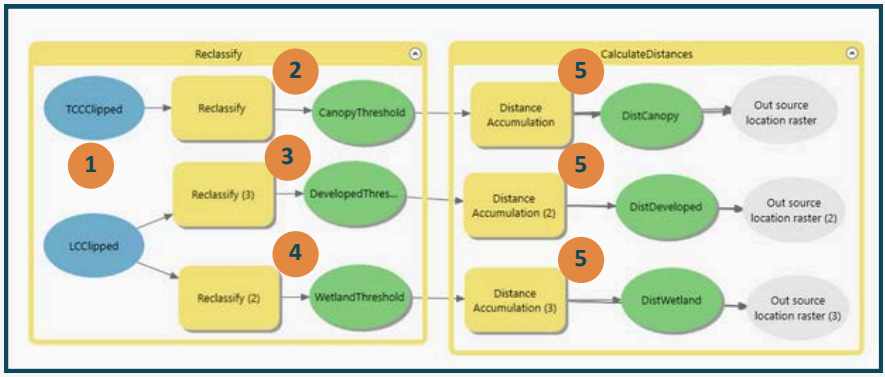
LCClipped



TCCClipped

Model 2: Calculate Distances

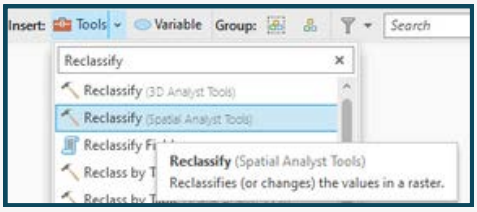
- **This suitability model will consider proximity from three landscape features (Tree Canopy Cover, Developed Land, Water & Wetlands)**
- **This model first creates threshold rasters from LCClipped and TCCClipped that identify where these specific landscape features occur**
- **Next, it uses these thresholds to calculate distance rasters showing distance from each pixel to closest occurrence of each feature.**
- **Complete model shown on right**

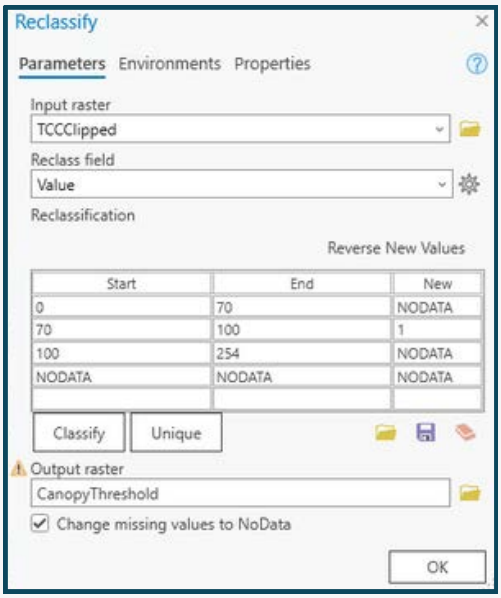


1 Open the empty "DeriveDistances" model. Using the "Variable" button in the toolbar, create 2 variables (blue).
From ClippedLayers.gdb geodatabase, load TCCClipped and LCClipped into the two variables.

2 From Tree Canopy Cover, we will identify all of the pixels where canopy cover is greater than or equal to 70%. Add the Reclassify tool and configure it as follows:

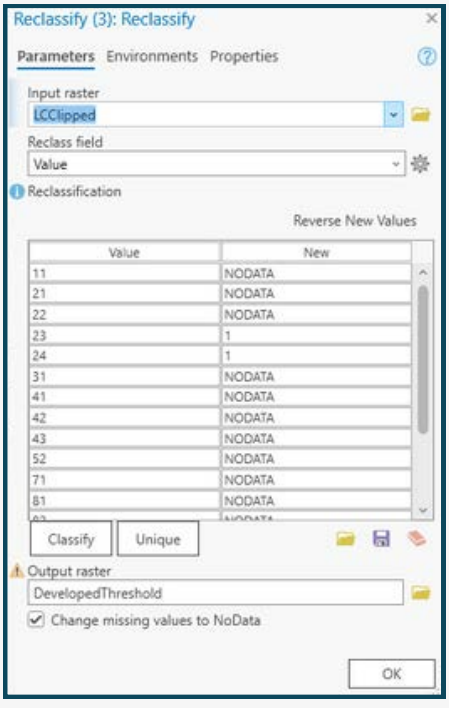
- Input Raster: Scroll down to model variables and select "TCCClipped".
- Reclass field: Select "Value" (indicates the percentage canopy cover)
- Classify the values such that values 70-100 are assigned a new value of 1, while everything else gets a value of NODATA.
- Output raster: Save as "CanopyThreshold" within the "Distance.gdb" geodatabase.





3 From Land Cover, we will identify all of the pixels where there is Medium or High Intensity Development (values 22, 23). Add the Reclassify tool and configure it as follows:

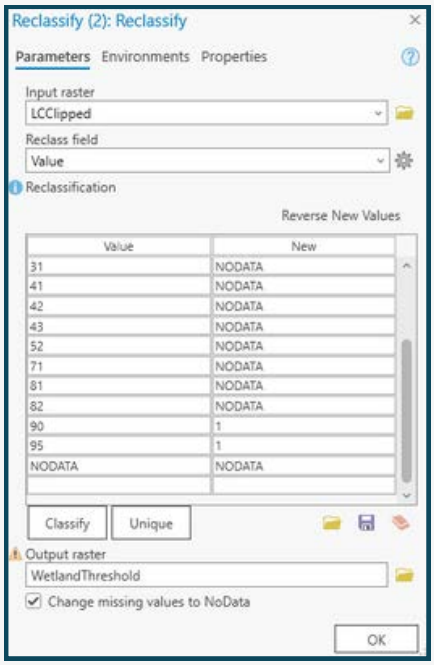
- Input Raster:
  - Scroll down to model variables and select "LCClipped".
- Reclass field
  - Select "Value" (indicates the land cover categories)
- Classify the values such that 23 and 24 are assigned a new value of 1, while everything else gets a value of NODATA.
- Output raster:
  - Save as "DevelopedThreshold" within the "Distance.gdb" geodatabase.



Model 2: Calculate Distances (Continued)

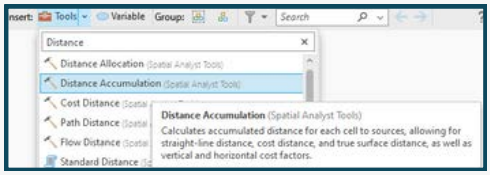
4 From Land Cover, we will identify all of the pixels where there is Water or Wetland (values 11, 90, 95). Add the Reclassify tool and configure it as follows:

- Input Raster:
  - Scroll down to model variables and select “LCClipped”.
- Reclass field
  - Select “Value” (indicates the land cover categories)
- Classify the values such that 11, 90, and 95 are assigned a new value of 1, while everything else receives NODATA.
- Output raster:
  - Save as “DevelopedThreshold” within the “Distance.gdb” geodatabase.



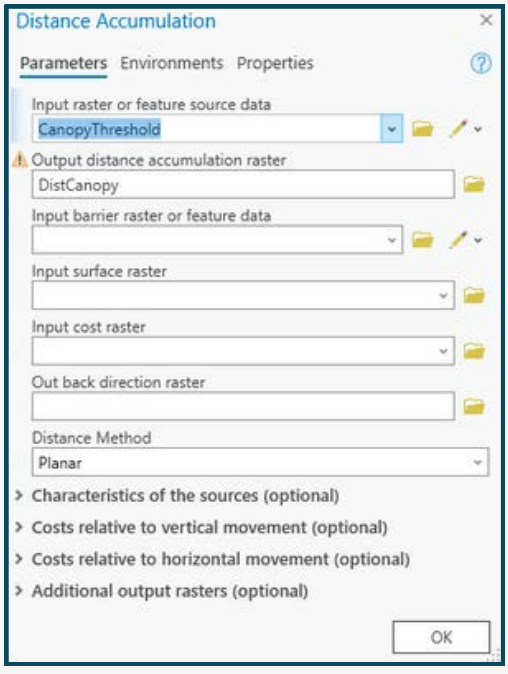
5 From each of the threshold rasters, calculate distance rasters using the “Distance Accumulation” tool. Configure it as follows:

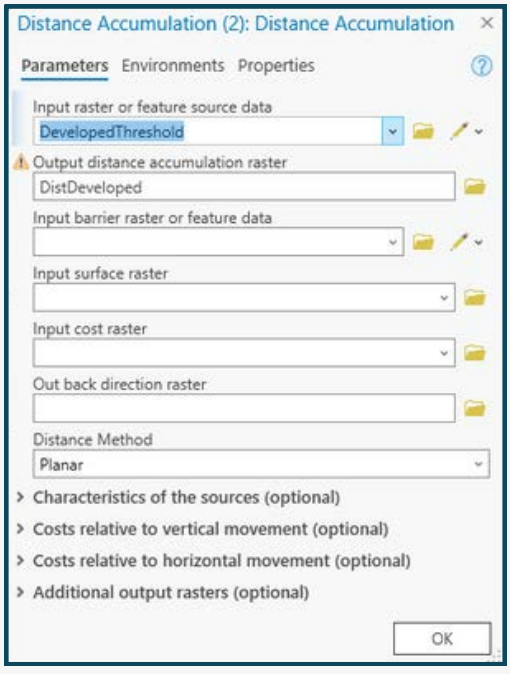
- Input raster or feature source data:
  - Scroll down to model variables and select “CanopyThreshold”.
- Output distance accumulation raster:
  - Save as “DistCanopy” within the “Distance.gdb” geodatabase.
- Distance Method:
  - Planar

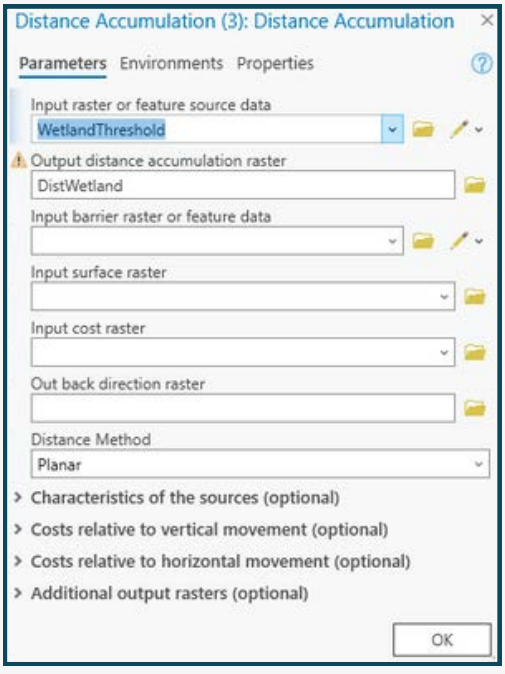


Repeat these steps for the other two distance rasters with the following replacements:

- Input: “DevelopedThreshold”, Output: “DistDeveloped”
- Input: “WetlandThreshold”, Output: “DistWetland”







Model 2: Calculate Distances (Outputs)

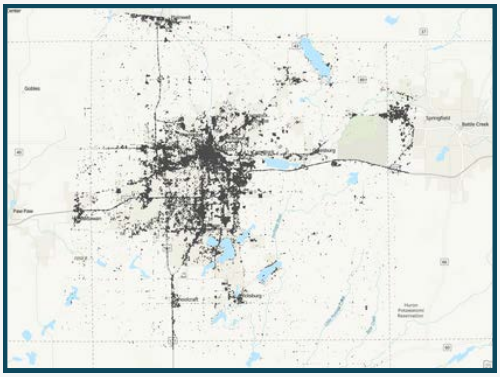
Click the Run button to execute the DeriveDistances model. Here are the layers that have been created:

1. Threshold Rasters (stored within Distance.gdb) - can be used to illustrate distribution of key habitat determinants
   - CanopyThreshold - Pixels where canopy is at least 70% canopy cover
   - DevelopedThreshold - Pixels with either medium or high intensity development
   - WetlandThreshold - Pixels with either water or wetland

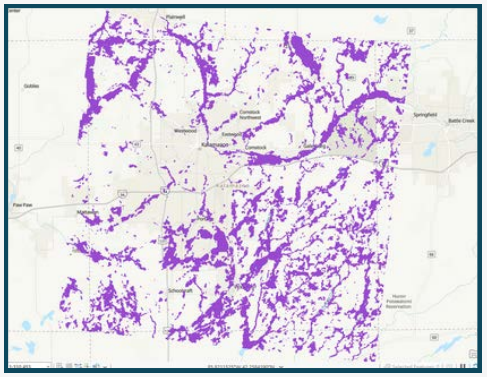
2. Distance Rasters (stored within Distance.gdb) - will be scaled and then used as criteria for suitability model
   - DistCanopy - Distance from closest pixel of at least 70% canopy cover
   - DistDeveloped - Distance from closest pixel of either medium or high intensity development
   - DistWetland - Distance from closest pixel of either water body or wetland

CanopyThreshold

DevelopedThreshold



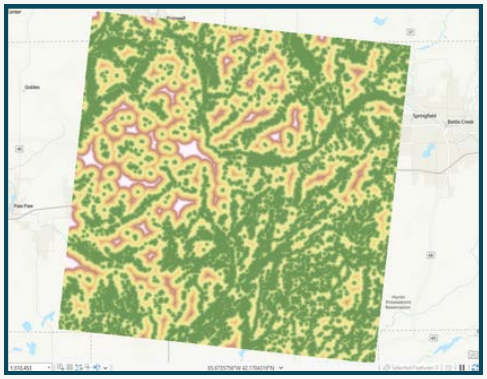
WetlandThreshold



DistCanopy

DistDeveloped

DistWetland



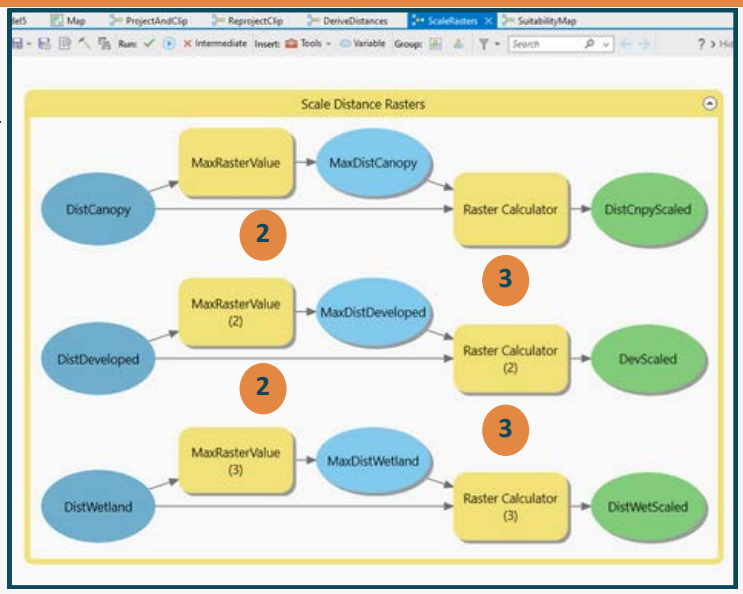
Model 3: Scale Rasters

The distance rasters have been now been created, but the ranges and meanings of these values vary.
We need to transform each distance raster so that its values are on a scale of 0-1 (where 1 is ideal habitat and 0 is least optimal). To do this, we will divide each pixel in the distance raster by the max pixel value in that raster.

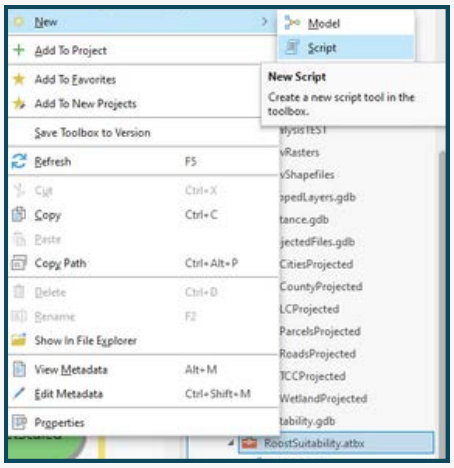
However, in the distance rasters, values increase as they get farther from the target feature. Depending on the desirability of the feature, lower or higher distance values might be preferable. Consider the features in the model:

- **Tree Canopy Cover is desirable so close distance (near 0) values should actually score high**
- **Water/wetlands are desirable so close distance (near 0) values should actually score high**
- **Development is undesirable so close distance (near 0) values appropriately score low.**

Thus for Tree Canopy Cover and Water/Wetlands, the scale needs to be flipped. This can be done by multiplying the scaled values by -1 and then adding 1.



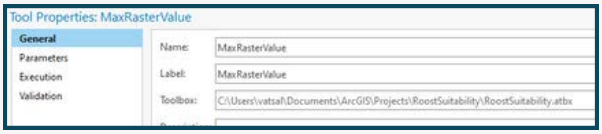
1 To calculate the maximum pixel values for each distance raster, create a python script component that receives a raster file and returns the maximum value.
Right-click on the "RoostSuitability.atbx" toolbox in the Catalog pane, and create a new Script.

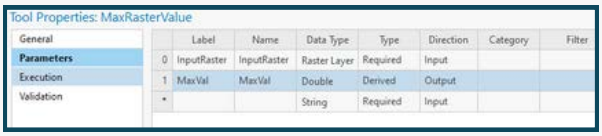


A properties window for the script should appear.
In the General tab, set the Name and Label to "MaxRasterValue".

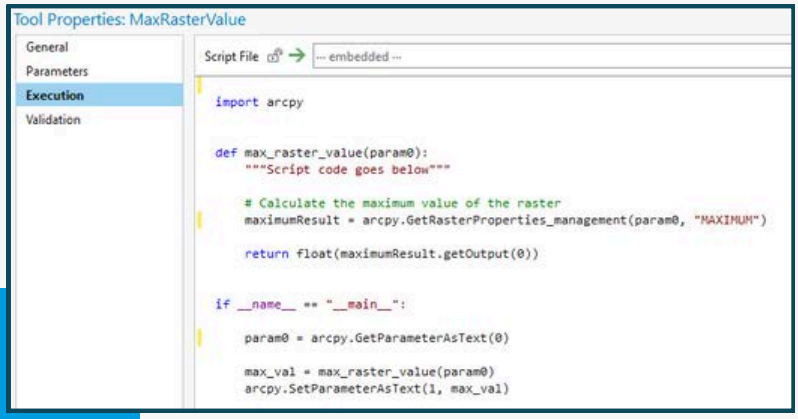
In the Parameters tab, create entries for the input raster file and the output value as follows:

- Parameter 0:
  - Label: InputRaster
  - Name: InputRaster
  - Data Type: Raster Layer
  - Type: Required
  - Type Direction: Input
- Parameter 1:
  - Label: MaxVal
  - Name: MaxVal
  - Data Type: Double
  - Type: Derived
  - Direction: Output





In the Execution tab, enter the following code snippet which instructs the script to calculate the max value of the input parameter and return it as an output:




```
import arcpy

def max_raster_value(param0):
    """Script code goes below"""

    # Calculate the maximum value of the raster
    maximumResult = arcpy.GetRasterProperties_management(param0, "MAXIMUM")

    return float(maximumResult.getOutput(0))

if __name__ == "__main__":

    param0 = arcpy.GetParameterAsText(0)

    max_val = max_raster_value(param0)
    arcpy.SetParameterAsText(1, max_val)
```

Model 3: Scale Rasters (Continued)

2 Load the three distance rasters from “Distance.gdb” into the model as variables:

- DistCanopy
- DistDeveloped
- DistWetland

To add the script to the model, drag MaxRasterValue from the Catalog Pane into the model. It will display on the model as a component similar to the other tools. Open the component and configure it by selecting a raster variable as the “Input Raster” parameter.

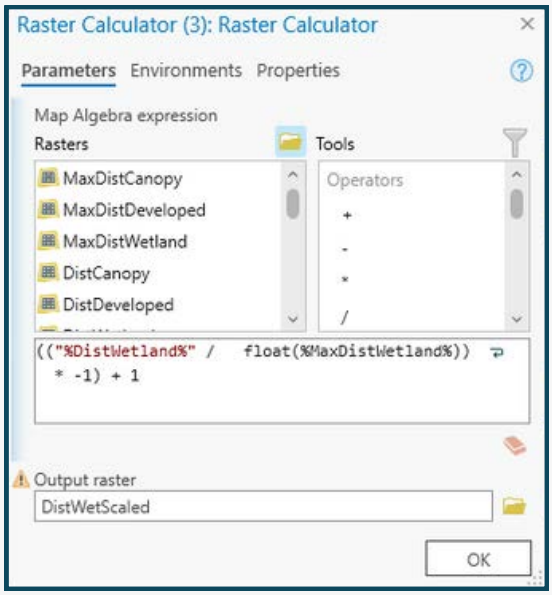
Add the script 3 times and calculate the max raster values for each of the three distance rasters. Rename the output value components from the script respectively to the following:

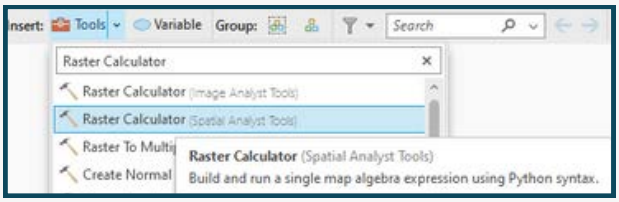
- MaxDistCanopy
- MaxDistDeveloped
- MaxDistWetland

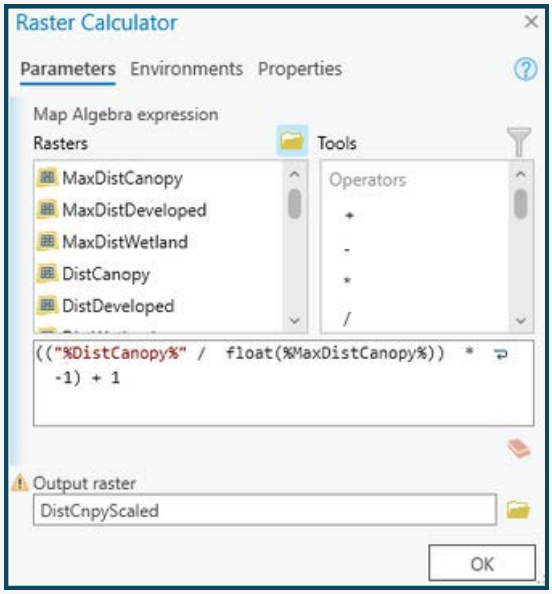
3 Search for the “Raster Calculator” tool and add it 3 times to the model. Enter the formulas from the images to calculate the following scaled rasters:

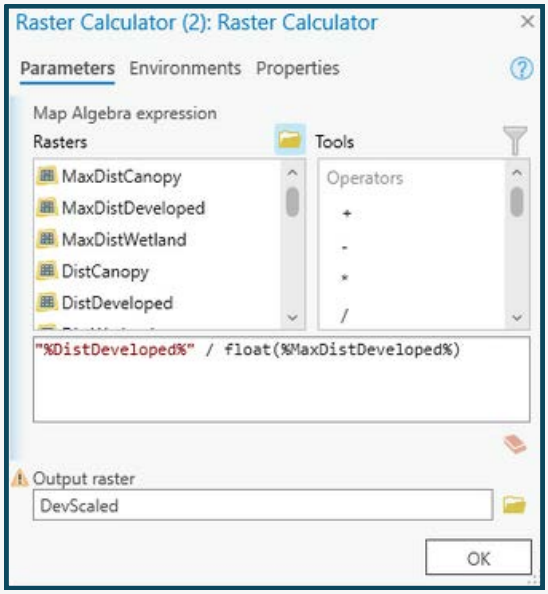
- DistCnpyScaled - scale the values and flip the scale
- DevScaled - scale the values only
- DistWetScaled - scale the values and flip the scale

Make sure the output rasters are stored in the “Distance.gdb” geodatabase.









Model 3: Scale Rasters (Outputs)

Click the Run button to execute the ScaleRasters model. Of the layers created, here are the ones we will continue to use as the analysis progresses:

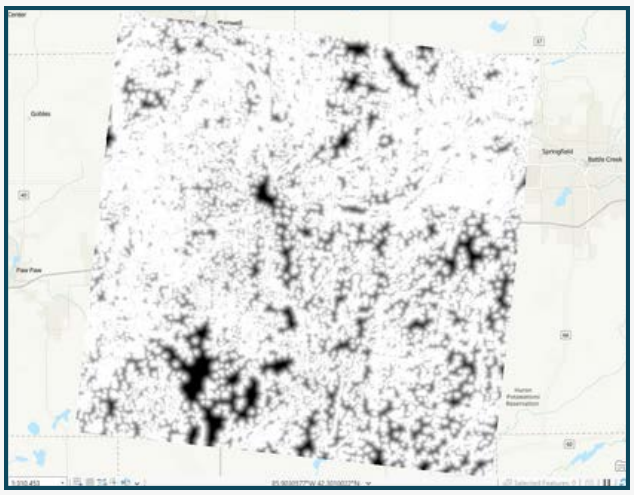
1

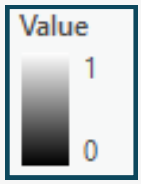
Scaled Distance Rasters (stored within Distance.gdb) - will be used as criteria for suitability model. Values close to 0 are not suitable habitat, while values close to 1 suggest high quality habitat.

- DistCnpyScaled - Scaled distance from closest pixel of at least 70% canopy cover
  - 0 (far from canopy), 1(closest to canopy)
- DevScaled - Scaled distance from closest pixel of either medium or high intensity development
  - 0 (close to intense development), 1(far from intense development)
- DistWetScaled - Scaled distance from closest pixel of either water body or wetland
  - 0 (far from wetlands), 1 (close to wetlands)

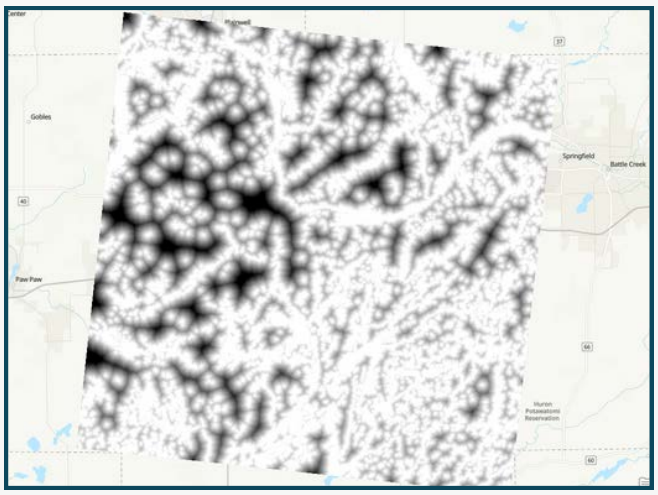
Note: the colors for the three layers are now all on the same scale.

DistCnpyScaled

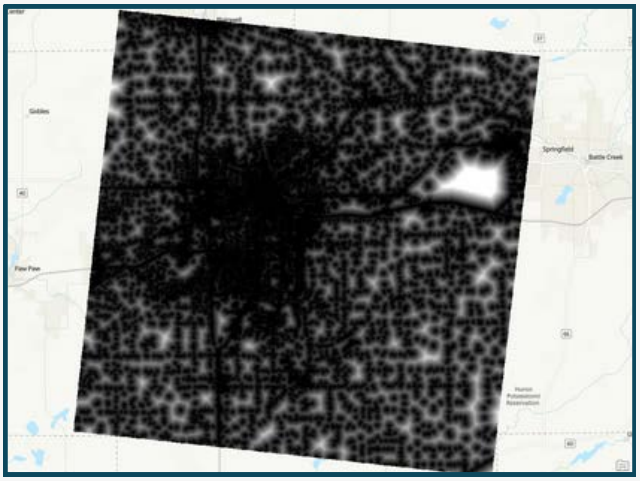




DistWetScaled



DevScaled



Model 4: Suitability Analysis

Habitat suitability analysis will calculate a score for each pixel in the county by adding up the scaled values of the relevant landscape features.

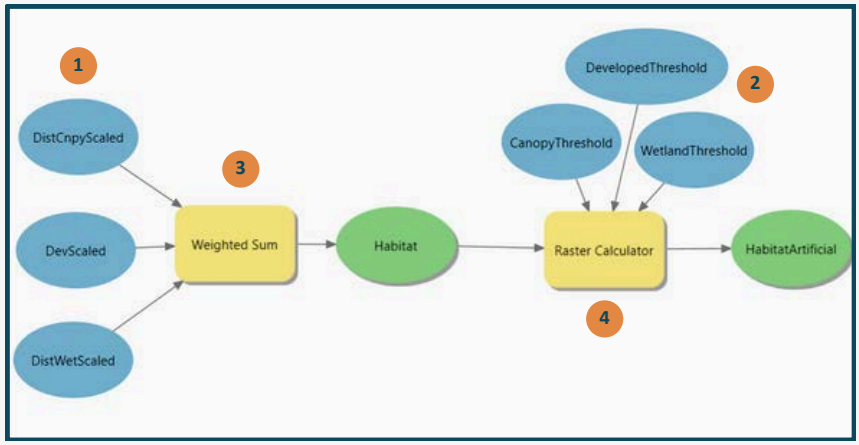
The 3 features that suggest high quality habitat are 1) proximity to high tree canopy cover, 2) distance away from intensely developed areas, and 3) proximity to water and wetlands.

Further, we specifically are not focusing on installing artificial roosts in certain kinds of places.

- **Roosts should not be installed in intensely developed areas**
- **Roost installation and maintenance may not be practical within water bodies or wetlands**
- **Roost occupancy is low within dense forest because there are likely enough natural roost options**

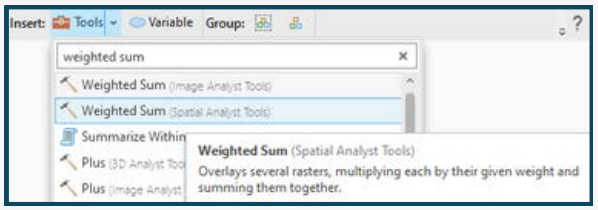
Recall that we previously created threshold rasters stored in "Distance.gdb" ("CanopyThreshold", "DevelopedThreshold", and "WetlandThreshold") that show only the locations where these features are present. After creating the habitat suitability map, locations from these thresholds can be excluded from the habitat suitability map to create an artificial roost suitability map.

The diagram shows the complete "SuitabilityMap" model, which creates both 1) a habitat suitability map, and 2) an artificial roost suitability map.

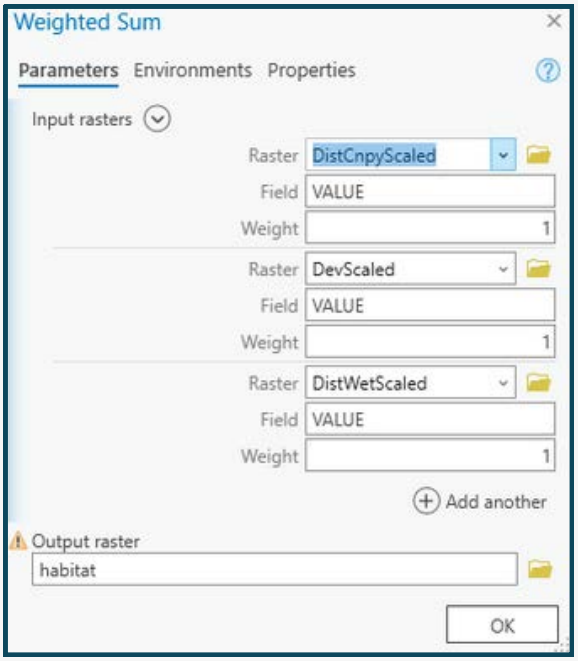


1 Open the empty "SuitabilityMap" model. Using the "Variable" button in the toolbar, create 3 variables (blue) of data type "Raster Layer". From "Distance.gdb" geodatabase, load DistCnpyScaled, DevScaled, and DistWetScaled into the three variables.

2 Create 3 more variables for the threshold rasters. Also make these of data type "RasterLayer". Load the "CanopyThreshold", "DevelopedThreshold", and "WetlandThreshold" layers from "Distance.gdb" into the respective variables.



3 Analyze habitat suitability using the scaled distance rasters as components for a weighted sum. In the toolbar, search for "Weighted Sum" and add it to the model. Configure the weighted sum as follows:



- Input Raster 1
  - Raster: Select "DstCnpyScaled" from Model Variables in the dropdown
  - Field: Select "VALUE" from the dropdown
  - Weight: 1
- Input Raster 2
  - Raster: Select "DevScaled" from Model Variables in the dropdown
  - Field: Select "VALUE" from the dropdown
  - Weight: 1
- Input Raster 3
  - Raster: Select "DistWetScaled" from Model Variables in the dropdown
  - Field: Select "VALUE" from the dropdown
  - Weight: 1
- Output raster: Name the result "Habitat" and store it in the "Suitability.gdb" geodatabase

Note: We will weight each landscape feature equally. If you decide certain landscape attributes are more important than others change the "Weight" values accordingly.

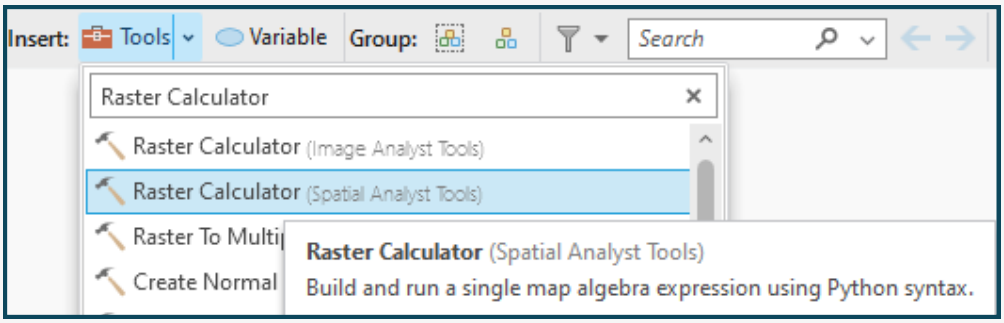
Model 4: Suitability Analysis (Continued)

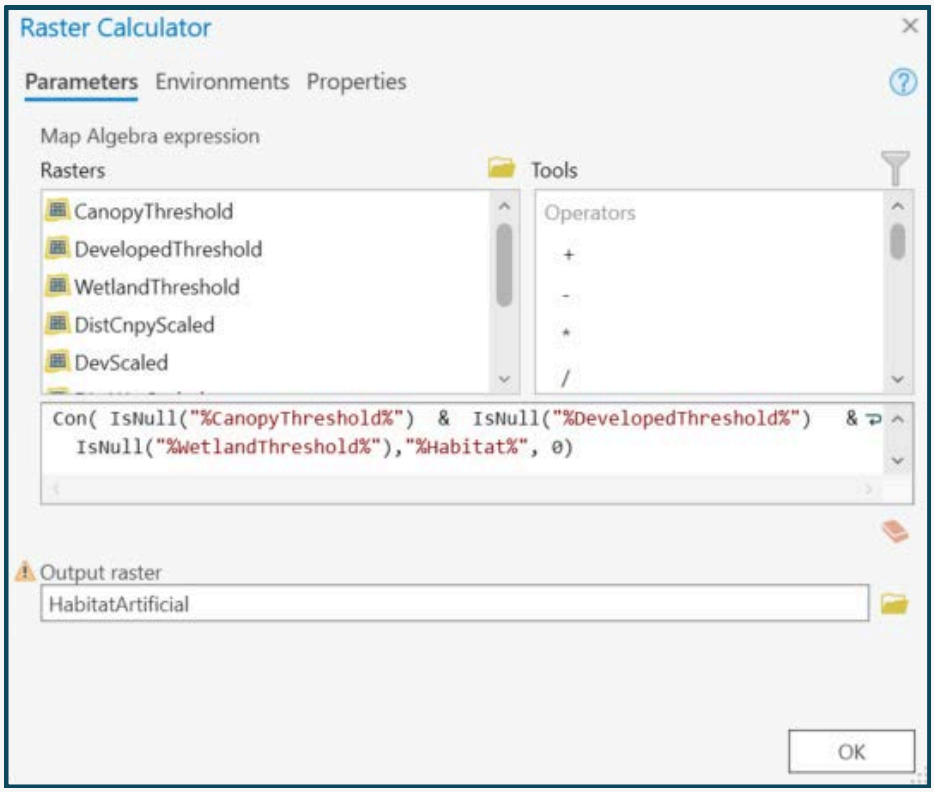
4 Now that the habitat suitability map has been created, create the artificial roost suitability map by removing the pixels from it that overlap with dense canopy cover, intense development, or water/wetlands.
Search for the "Raster Calculator" tool and add it to the model.

Enter the formula from the image within the Raster calculator.

- "Con" is a conditional operator. Everything between the first comma is the condition.
  - This condition translates to "The pixel is not identified within the threshold rasters as dense canopy, and not as intense development, and not as wetland".
- If the condition is true, then the output raster will retain the value from the "Habitat" raster.
- If the condition is not true, the output raster will have a value of 0 at that pixel.

Name the Output raster "HabitatArtificial" and store it in the "Suitability.gdb" geodatabase.



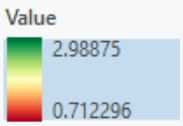


Model 4: Suitability Analysis (Outputs)

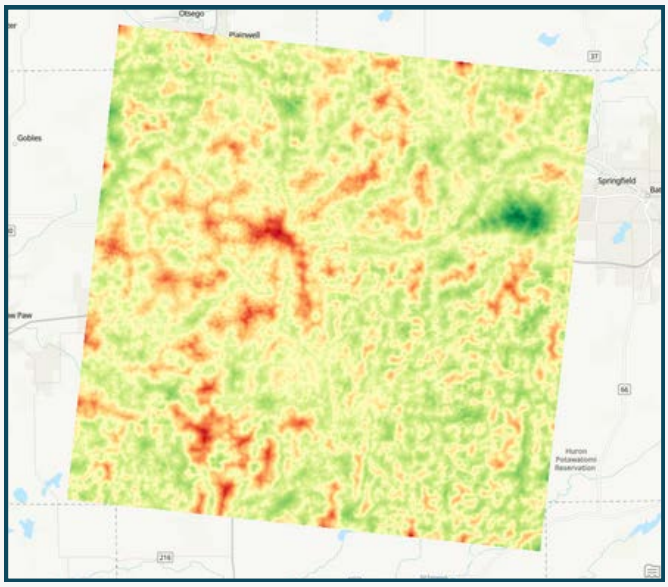
Click the Run button to execute the SuitabilityMap model.

1. Habitat - This first layer is the Habitat Suitability map. Higher scores are driven by a combination of 1) Proximity to dense forest canopy cover, 2) Distance away from intense development, and 3) Proximity to Water/Wetlands. High values suggest that high habitat quality and that bats may already prefer the area.

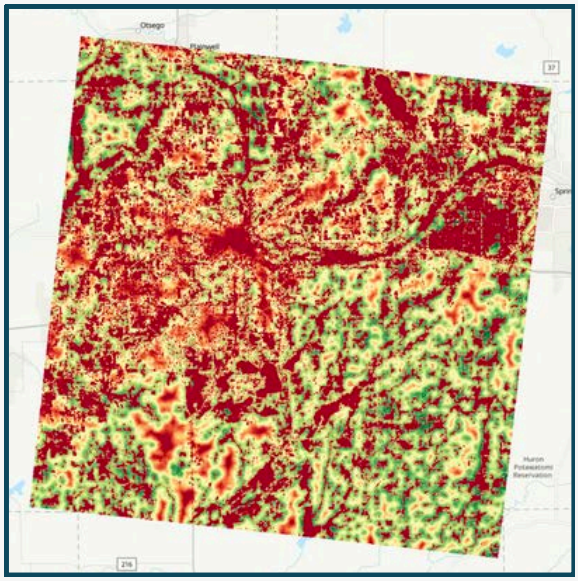
2. HabitatArtificial - The second layer removes the exact locations of dense forest canopy, wetlands, and intense development from the habitat suitability map and replaces those pixels with a value of 0.
As a reminder, this is because:
   - Roosts should not be installed in intensely developed areas
   - Roost installation and maintenance may not be practical within water bodies or wetlands
   - Roost occupancy is low within dense forest because there are likely enough natural roost options



Habitat



HabitatArtificial



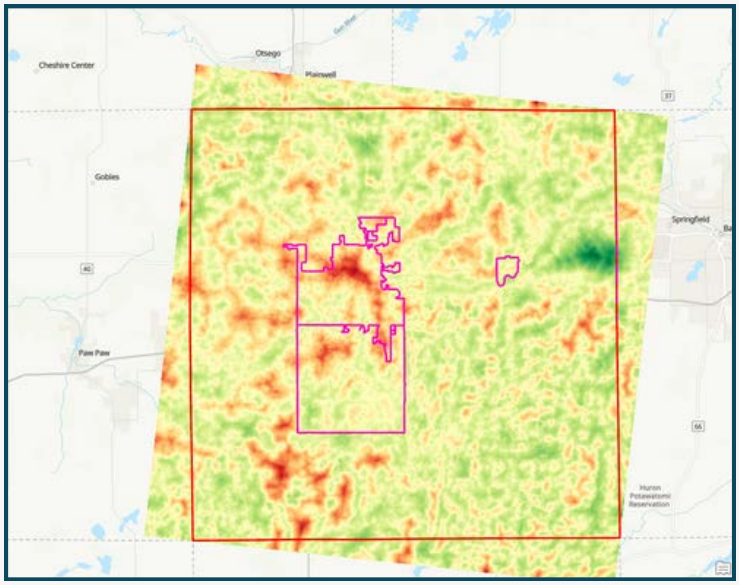
Note how the two layers are identical except that HabitatArtificial has white areas (where the value is 0) representing the places where artificial roost construction will not be prioritized even if there is suitable habitat.

On the next page, we will discuss how to evaluate and make maps from these layers. These maps and analyses can aid decision making related to bat box construction or broader conservation goals.

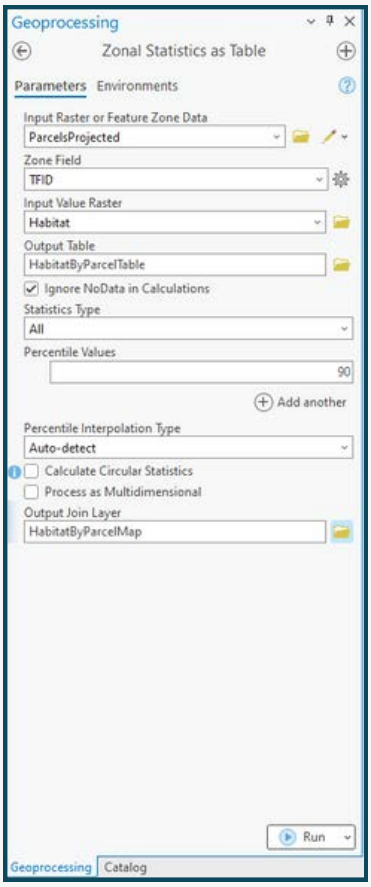
Using Suitability Outputs

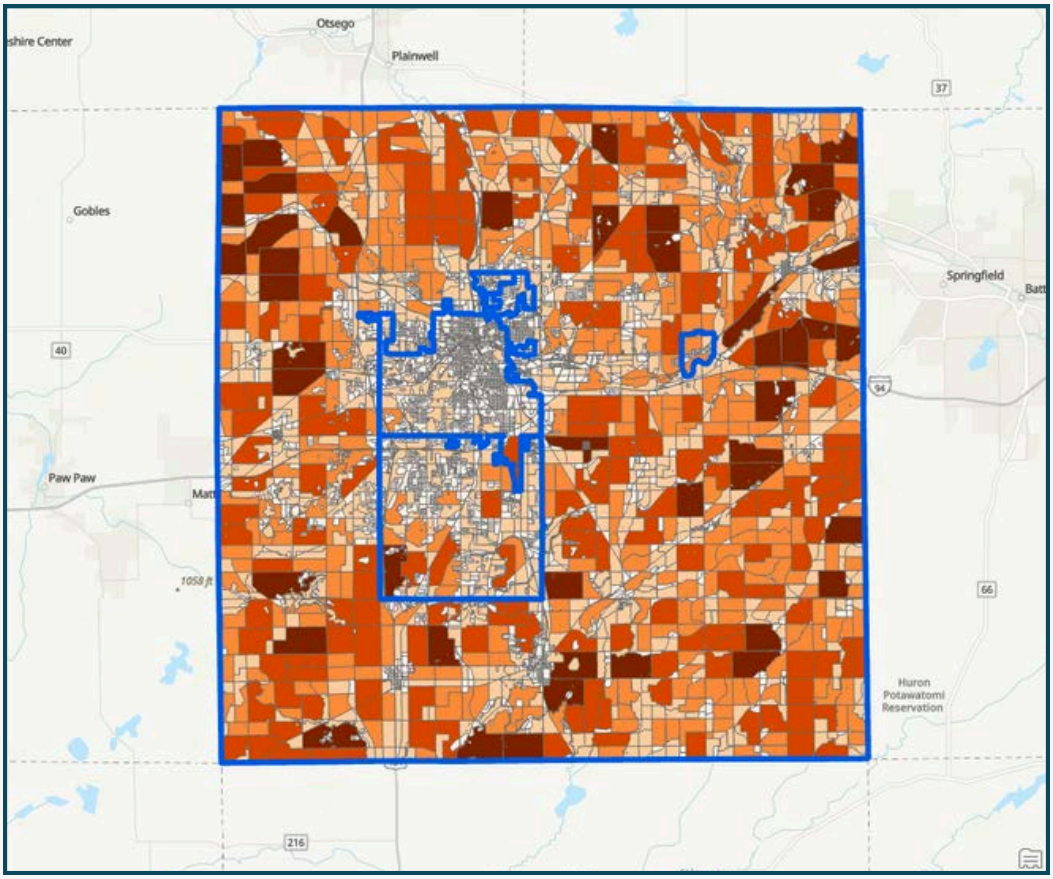
Here are some ways to visualize or further analyze the suitability maps for decision making:

1 Visualize the habitat suitability by overlaying the “CountyProjected” and “CitiesClipped” layers over a suitability map. Other layers such as roads can be overlayed on top of this to better visualize high quality habitat at the City and County levels.



2 To aggregate the data within local boundaries (in this case land parcels), use the “Zonal Statistics as Table” tool and for the Input Raster or Feature Zone Data use local boundaries polygons such as “ParcelsProjected” stored in “ProjectedFiles.gdb” Make sure to create an Output Join Layer to create a shapefile that contains the calculated statistics. Calculating these statistics for either the habitat suitability map or the bat box suitability map can provide information such as which neighborhoods have the highest average suitability scores for habitat quality or prioritization for bat box installation.





This material is based upon work supported by the Department of Energy and the Michigan Energy Office (MEO) under Award Number EE0008653 as part of the Catalyst Communities program. Find this document and more about the CLC Fellowship that supported this project at graham.umich.edu/clcf.