----------Read me file ----------

Regional Wildlife Disease Hazard Software

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Overview of the *Regional Wildlife Disease Hazard Software*

The *Regional Wildlife Disease Hazard Software* displays the hazards associated with the introduction and spread of chronic wasting disease (CWD) in free ranging white-tailed deer (*Odocoileus virginianus*) in select states and provinces in the eastern United States (US) and Canada (CAN). The *Regional Wildlife Disease Hazard Software* was adapted from the *Wildlife Disease Hazard Software* (Hanley et al. 2021) to display pooled data and results up to the continental scale. The R scripts of the *Regional Wildlife Disease Hazard Software* contain a sequential network of commands that format the geospatial files, surveillance (testing) data, hazard (anthropogenic) data, and demographic (deer) data and launch the user interface (UI) of

the interactive software to depict pooled results at the continental scale. The *Regional Wildlife Disease Hazard Software* includes (redacted) hazard and (redacted) deer demographic data from Alabama, Arkansas, Connecticut, Florida, Georgia, Indiana, Iowa, Kentucky, Louisiana, Maryland, Michigan, Minnesota, Mississippi, New Hampshire, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, Tennessee, Virginia, and Wisconsin, US and Ontario, CAN, but can be modified to include other states and provinces.

The *Regional Wildlife Disease Hazard Software* contains four `R` scripts:

"`0_Regional_Hazard_Pre_Processing.R`" script,
"`1_Regional_Hazard_Data_Prep.R`" script,
"`2_Regional_Hazard_App.R`" script,
"`3_Regional_Hazard_Command_Center.R`" script.

The `0_Regional_Hazard_Pre_Processing.R` script of the *Regional Wildlife Disease Hazard Software* creates the geospatial and related files containing administrative boundaries for all included states and provinces in the structural format needed for immediate upload into the `2_Regional_Hazard_App.R` script of the *Regional Wildlife Disease Hazard Software*.

The `1_Regional_Hazard_Data_Prep.R` script of the *Regional Wildlife Disease Hazard Software* converts, for each state (or province) the demographic (white-tailed deer) data, hazard (anthropogenic) data, and CWD surveillance (disease testing) data processed in Mitchell et al. (2021) into the structural format needed for immediate upload into the `2_Regional_Hazard_App.R` script of the *Regional Wildlife Disease Hazard Software*.

The `2_Regional_Hazard_App.R` script of the *Regional Wildlife Disease Hazard Software* intakes the autosaved geospatial files from the execution of the `0_Regional_Hazard_Pre_Processing.R` script and the autosaved data from the execution of the `1_Regional_Hazard_Data_Prep.R` script and launches the interactive software that displays the results. Thus, the `0_Regional_Hazard_Pre_Processing.R`, `1_Regional_Hazard_Data_Prep.R`, and `2_Regional_Hazard_App.R` scripts of the *Regional Wildlife Disease Hazard Software* must run in sequence.

With one click, `3_Regional_Hazard_Command_Center.R` script of the *Regional Wildlife Disease Hazard Software* runs the appropriate sequence and set of scripts of the *Regional Wildlife Disease Hazard Software*:
`0_Regional_Hazard_Pre_Processing.R`,
`1_Regional_Hazard_Data_Prep.R`, and
`2_Regional_Hazard_App.R` scripts.

Any data available for any state or province in North America may be included in the interface. Missing data do not hinder the ability to run the software. Please see the **Instructions to add data to the *Regional Wildlife Disease Hazard Software*** section below.

Inputs needed to run the *Regional Wildlife Disease Hazard Software*

Data necessary to run the `0_Regional_Hazard_Pre_Processing.R` script of the *Regional Wildlife Disease Hazard Software* include:

0-i. Raw geospatial files containing administrative boundaries for the US and Canada.
*Note: The Cartographic Boundary and TIGER line files (US Census Bureau 2019; 2020) necessary to create the appropriate files for the US states are procured using command lines directly in the script. The files necessary for Canada (Statistics Canada 2019), however, require additional steps to procure from an outside source. See **Steps 5-6** in the **Regional Wildlife Disease Hazard Software user tutorial** section (below).*

0-ii. A csv file containing a list of all participating state and province names in a single column (for more details see ***Step 7*** below):
"`All_states.csv`"
Note: This script will automatically create a single set of geospatial files and related files consisting of all states and provinces included in "`All_States.csv`" *and should only be run once, unless additional states are added to* "`All_States.csv`" *after the initial run.*

Data necessary to run the `1_Regional_Hazard_Data_Prep.R` script of the *Regional Wildlife Disease Hazard Software* include:

1-i. Geospatial files autosaved during the execution of the `0_Regional_Hazard_Pre_Processing.R` script containing the county (or other administrative area) boundaries of all participating states and provinces:
"`All_counties.dbf`"
"`All_counties.prj`"
"`All_counties.shp`"
"`All_counties.shx`"

1-ii. Pre-processed hazard data summaries by county (or other administrative area) for all participating states and provinces (created for each state and province in Hanley et al. 2021):
"`County_Areas_(state name).txt`"
"`County_Captive_(state name).txt`"
"`County_Density_(state name).txt`"
"`County_Fecundity_(state name).txt`"
"`County_Harvest_(state name).txt`"
"`County_Hazard_(state name).txt`"
"`County_Load_(state name).txt`"
"`County_Mortality_(state name).txt`"
"`County_Processor_(state name).txt`"
"`County_Taxidermy_(state name).txt`"

1-iii. A csv file containing a list of all state and province names with surveillance (testing) data in a single column (for more details see ***Step 8*** below):
"Data_States.csv"
Note: this list may differ from the one in "All_States.csv".

The hazard data (**1-ii**) are not included in this *Regional Wildlife Disease Hazard Software* packet. Templates with redacted data ("999999") are included in this packet to run the software. Data summaries can be created for states (or provinces) with Hanley et al. (2021), alternatively, templates can be modified to include real data by replacing "999999" in all templates.

Data necessary to run the 2_Regional_Hazard_App.R script of the *Regional Wildlife Disease Hazard Software* include:

2-i. Geospatial files *autosaved* during the execution of the 0_Regional_Hazard_Pre_Processing.R script containing the county (or other administrative area) boundaries of all participating states and provinces:
"All_counties.dbf"
"All_counties.prj"
"All_counties.shp"
"All_counties.shx"

2-ii. Data file outputs *autosaved* during the execution of the 1_Regional_Hazard_Data_Prep.R script:
"Area_All.txt"
"Captive_All.txt"
"Density_All.txt"
"Fecundity_All.txt"
"Harvest_All.txt"
"Hazard_All.txt"
"Load_All.txt"
"Mortality_All.txt"
"Name_All.txt"
"Processor_All.txt"
"Taxidermy_All.txt"

2-iii. Text files *autosaved* during the execution of the 0_Regional_Hazard_Pre_Processing.R script containing the geographic center of the region of interest:
"All_Latitude.txt"
"All_Longitude.txt"

Data necessary to run the 3_Regional_Hazard_Command_Center.R script of the *Regional Wildlife Disease Hazard Software* include:

3-i. Raw geospatial files containing administrative boundaries for the US and Canada.

Note: The Cartographic Boundary and TIGER line files (US Census Bureau 2019; 2020) necessary to create the appropriate files for the US states are procured automatically by the script using command lines. However, additional steps are required to procure the files necessary for Canada (Statistics Canada 2019) from an outside source. See ***Steps 5-6*** *in the* ***Regional Wildlife Disease Hazard Software user tutorial*** *section (below).*

3-ii. A csv file containing a list of all participating state and province names in a single column (for more details see ***Step 7*** below):
"`All_states.csv`"

3-iii. Pre-processed data summaries for all participating states and provinces (created for each state and province in Hanley et al. 2021):
"`County_Areas_(state name).txt`"
"`County_Captive_(state name).txt`"
"`County_Density_(state name).txt`"
"`County_Fecundity_(state name).txt`"
"`County_Harvest_(state name).txt`"
"`County_Hazard_(state name).txt`"
"`County_Load_(state name).txt`"
"`County_Mortality_(state name).txt`"
"`County_Processor_(state name).txt`"
"`County_Taxidermy_(state name).txt`"

3-iv. A csv file containing a list of all state and province names with surveillance (testing) data in a single column (for more details see ***Step 8*** below):
"Data_States.csv"
Note: this list may differ from the one in "All_States.csv".

The hazard data (**3-iii**) are not included in this *Regional Wildlife Disease Hazard Software* packet. Templates with redacted data ("`999999`") are included in this packet to run the software. Data summaries can be created for states (or provinces) with Hanley et al. (2021), alternatively, templates can be modified to include real data by replacing "`999999`" in all templates. Variables in the templates are defined as:

Areas: the area in square kilometers of each county (or other administrative area);
Captive: the number of captive cervid facilities that are known to exist in each county (or other administrative area);
Density: the estimated number of deer (per sq. kilometer) that occur in each county (or other administrative area);
Fecundity: the average number of fawns born to each doe per year in each county (or other administrative area);
Harvest: the average number of deer harvested by hunters via legal hunting activities per year in each county (or other administrative area);
Hazard: the hazard score that arises for each county (or other administrative area) from the model by Schuler et al. (*in preparation*);

Load: the cumulative number of confirmed cases of CWD in wild deer in each county (or other administrative area) (proxy for the environmental prion load);
Mortality: the average mortality of deer per year in each county (or other administrative area). Mortality is equal to one over survival.
Processor: the number of operational wild deer meat processing businesses in each county (or other administrative area);
Taxidermy: the number of operational taxidermy businesses in each county (or other administrative area);

***Regional Wildlife Disease Hazard Software* user tutorial**

Preparing and running the Regional Wildlife Disease Hazard Software

Step 1: Open R and verify that you are running the appropriate version of the R Software (R Core Team 2020). The appropriate version is `4.0.2 (2020-06-22) -- "Taking Off Again" Copyright (C) 2020 The R Foundation for Statistical Computing Platform: x86_64-w64-mingw32/x64 [64-bit]`.

Step 2: Install the appropriate versions of the dependencies (R packages) in R. Packages include:

(1) "`devtools`" version 2.3.2
(2) "`dplyr`" version 1.0.2
(3) "`leaflet`" version 2.0.3
(4) "`leaflet.extras`" version 1.0.0
(5) "`leafpop`" version 0.0.6
(6) "`RColorBrewer`" version 1.1-2
(7) "`rgdal`" version 1.5-18
(8) "`rgeos`" version 0.5-5
(9) "`rgl`" version 0.100.54
(10) "`raster`" version 3.4-5
(11) "`rmapshaper`" version 0.4.4
(12) "`maptools`" version 1.5-2
(13) "`shiny`" version 1.5.0
(14) "`shinyBS`" version 0.61
(15) "`shinycssloaders`" version 1.0.0
(16) "`shinydashboard`" version 0.7.1
(17) "`sf`" version 0.9-6
(18) "`sp`" version 1.4-4
(19) "`stringr`" version 1.4.0
(20) "`tidyr`" version 1.1.2
(21) "`tigris`" version 1.0

To install a particular version of an R package, run the code:
`library(devtools)`
`devtools::install_version("package name", version = "#.#.#").`

Step 3: Create a folder on your computer that will function as your working directory.

3-a: Create a folder, then name it in accordance with your project. This folder will be your working directory.

3-b: Set the path to the working directory in R by clicking the R Console, clicking "`File`", clicking "`Change dir…`", then navigating through the file paths to your working directory. Click "`OK`".

3-c: Verify that R has the correct path to your working directory by clicking the R console, typing "`dir()`", and hitting enter. The file names of the contents of your working directory will print in the R console.

Step 4: Prepare the *Regional Wildlife Disease Hazard Software* on your machine.

4-a: Download, unzip, and save *Regional Wildlife Disease Hazard Software* contents in your working directory.

4-b: To double check all contents are in your working directory, click the R console, type "`dir()`", and hit enter. The file names of the contents of your working directory will print in the console.

Step 5. Download and prepare the census division unit shapefiles from Statistics Canada.

5-a. Go to *www12.statcan.gc.ca/census-recensement/2011/geo/bound-limit/bound-limit-2016-eng.cfm.*

5-b. Select the following options: Language: "`English`"; Format: "`ArcGIS`"; Boundary files: "`Census division`" under "`Cartographic Boundary File`"; then click "`Continue`" to be directed to the download page.

5-c. Download the zipped folder (`lcd_000b16a_e.zip`).

5-d. Unzip the downloaded folder into the working directory.

Step 6. Download and prepare the geographic attribute file for the 2016 census year for Canada.

6-a. Go to *www12.statcan.gc.ca/census-recensement/2011/geo/ref/att-eng.cfm*.

6-b. Select the following options: Census year: `2016`; Format: "`Comma-separated values (.csv)`"; then click "`Continue`" to be directed to the download page.

6-c. Download the zipped folder (`2016_92-151_XBB_csv.zip`).

6-d. Unzip the downloaded folder into the working directory.

Step 7. Open the file titled "`All_States`" and verify the list of all regional state and province names in the single column named "`All_States`". This list is used by the *Regional Wildlife Disease Hazard Software* to create the geospatial files necessary to run the

application as well as read in and collate the hazard data for each participating state and province listed.

Note: This file must contain a list of all entities to be displayed in the Regional Wildlife Disease Hazard Software. To add a state (or province), please see ***Instructions to add data to the Regional Wildlife Disease Hazard Software*** *(below).*

States or provinces with spaces, such as "New York" should be written with the space. Do not include the country in the name. For example, type "New York" as "New York", not as "New York, USA". States and provinces should be listed in ascending alphabetical order (from A at top to Z at bottom).

Step 8. Create a csv file titled "`Data_States`" with a list of all state and province names with surveillance (testing) data in a single column named "`Data_States`". This list is used by the *Regional Wildlife Disease Hazard Software* to collate CWD environmental prion load totals for states (or provinces) with such data.

Note: States or provinces with spaces, such as "New York" should be written with the space. Do not include the country in the name. For example, type "New York" as "New York", not as "New York, USA". States and provinces should be listed in ascending alphabetical order (from A at top to Z at bottom).

Note: this list may differ from the one in "`All_States.csv`*".*

Step 9: Open in R the file named "`3_Regional_Hazard_Command_Center.R`".

Step 10: Hit "`Run all`".

Note: From this moment, your script will automatically call the appropriate libraries, then begin running the series of scripts of the Regional Wildlife Disease Hazard Software. Several lines of code will be executed without any further interaction from you. Your script will automatically load the geospatial files, initiate projections, crunch data, and sort data. This computational process is normal. All files are autosaved to your working directory. Finally, the script will open the user interface of the interactive app.

Step 11: Once done interacting with the UI, close the tab depicting the UI, stop the R code, and close the R program.

Instructions to add data to the *Regional Wildlife Disease Hazard Software*

The *Regional Wildlife Disease Hazard Software* was initially developed to accommodate the needs of a consortium of state and provincial wildlife agencies that opted to participate in the Surveillance Optimization Project for Chronic Wasting Disease (SOP4CWD; CHWL 2021). Accordingly, the list of states and provinces included in this packet reflect the current list of partnering agencies, but other states and provinces are welcome to join.

In the event additional states or provinces join, this software can accommodate their inclusion with ease. To add a state or province to the *Regional Wildlife Disease Hazard Software*:

Step i: Open the "`All_States.csv`" file.

i-a: Enter the name of the new state (or province) in the alphabetically appropriate row.

Note: States or provinces with spaces, such as "New York" should be written with the space. Do not include the country in the name. For example, type "New York" as "New York", not as "New York, USA". States and provinces should be listed in ascending alphabetical order (from A at top to Z at bottom).

i-b. Save the updated "`All_States.csv`" file to your working directory.

Step ii. If the new state (or province) has surveillance (testing) data, open the "`Data_States.csv`" file, and enter the name of the new state.

ii-a. Enter the name of the new state (or province) in the alphabetically appropriate row.

Note: States or provinces with spaces, such as "New York" should be written with the space. Do not include the country in the name. For example, type "New York" as "New York", not as "New York, USA". States and provinces should be listed in ascending alphabetical order (from A at top to Z at bottom).

Step iii: Reference Hanley et al. (2021) to create the following hazard summaries by county (or other administrative area) for the new state (or province):

"`County_Areas_(new state name).txt`"
"`County_Captive_(new state name).txt`"
"`County_Density_(new state name).txt`"
"`County_Fecundity_(new state name).txt`"
"`County_Harvest_(new state name).txt`"
"`County_Hazard_(new state name).txt`"
"`County_Load_(new state name).txt`"
"`County_Mortality_(new state name).txt`"
"`County_Processor_(new state name).txt`"
"`County_Taxidermy_(new state name).txt`"

Step iv: Complete **Steps 1-10** above.

*Note: If you previously completed **Steps 2-6** for another state (or province) (i.e., installed the appropriate packages, setup your working directory, prepared the Wildlife Disease Hazard Software, and downloaded and added the Canadian census division units shapefiles, and geographic attribute file to your working directory), you may skip **Steps 2-6.***

Technical details

0_Regional_Hazard_Pre_Processing.R script of the *Regional Wildlife Disease Hazard Software* was written under R version 4.0.2 (2020-06-22) -- "Taking Off Again" Copyright (C) 2020 The R Foundation for Statistical Computing Platform: x86_64-w64-mingw32/x64 (64-bit) and requires the packages: (1) "devtools" version 2.3.2 (Wickman et al. 2020), (2) "rgdal" version 1.5-18 (Bivand et al. 2020), (3) "tigris" version 1.0 (Walker 2020), (4) "stringr" version 1.4.0 (Wickman 2019), (5) "maptools" version 1.0-2 (Bivand and Lewin-Koh 2021), (6) "raster" version 3.4-5 (Hijmans 2020), (7) "dplyr" version 1.0.2 (Wickman et al. 2021), (8) "rmapshaper" version 0.4.4 (Teucher and Russell 2020), and (9) "rgeos" version 0.5-5 (Bivand and Rundel 2020).

1_Regional_Hazard_Data_Prep.R script of the *Regional Wildlife Disease Hazard Software* was written under R version 4.0.2 (2020-06-22) -- "Taking Off Again" Copyright (C) 2020 The R Foundation for Statistical Computing Platform: x86_64-w64-mingw32/x64 (64-bit) and requires the packages: (1) "devtools" version 2.3.2 (Wickman et al. 2020), (2) "rgdal" version 1.5-18 (Bivand et al. 2020), (3) "raster" version 3.4-5 (Hijmans 2020), (4) "rmapshaper" version 0.4.4 (Teucher and Russell 2020), and (5) "stringr" version 1.4.0 (Wickman 2019).

2_Regional_Hazard_App.R script of the *Regional Wildlife Disease Hazard Software* was written under R version 4.0.2 (2020-06-22) -- "Taking Off Again" Copyright (C) 2020 The R Foundation for Statistical Computing Platform: x86_64-w64-mingw32/x64 (64-bit), and requires the packages: (1) "devtools" version 2.3.2 (Wickman et al. 2020), (2) "shinydashboard" version 0.7.1 (Chang and Borges Ribeiro 2018), (3) "shiny" version 1.5.0 (Chang et al. 2020), (4) "leaflet" version 2.0.3 (Cheng et al. 2019), (5) "dplyr" version 1.0.2 (Wickman et al. 2021), (6) "leaflet.extras" version 1.0.0 (Karambelkar and Schloerke 2018), (7) "rgl" version 0.100.54 (Adler et al. 2020), (8) "shinyBS" version 0.61 (Bailey 2015), (9) "RColorBrewer" version 1.1-2 (Neuwirth 2014), (10) "sp" version 1.4-4 (Pebesma and Bivand 2005; Bivand et al. 2013), (11) "sf" version 0.9-6 (Pebesma 2018), (12) "rgdal" version 1.5-18 (Bivand et al. 2020), (13) "leafpop" version 0.0.6 (Appelhans and Detsch 2020), (14) "tidyr" version 1.1.2 (Wickman 2020), (15) "shinycssloaders" version 1.0.0 (Sali and Attali 2020), and (16) "rmapshaper" version 0.4.4 (Teucher and Russell 2020).

3_Regional_Hazard_Command_Center.R script of the *Regional Wildlife Disease Hazard Software* was written under R version 4.0.2 (2020-06-22) -- "Taking Off Again" Copyright (C) 2020 The R Foundation for Statistical Computing Platform: x86_64-w64-mingw32/x64(64-bit) and requires all the packages listed for the other scripts.

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Financial support

Financial support comes from (1) Michigan Disease Initiative – *Optimizing CWD Surveillance: Regional Synthesis of Demographic, Spatial, and Transmission-Risk Factors* (2019); (2) Tennessee Wildlife Resources Agency - *Modeling Risk of Infection for Individually Harvested Deer & Estimating Prevalence When Sampling is Limited* (2020); (3) Michigan Disease Initiative - *SOP4CWD Dashboard: A Web Application for Disease Visualization and Data-Driven Decisions* (2020); (4) Multistate Conservation Grant Program - *Surveillance Optimization Project for Chronic Wasting Disease: Streamlining a Web Application for Disease Visualization and Data-Driven Decisions* (2021).

Acknowledgements

We thank J. Fleegle, A. Korman, J. Peaslee, and four anonymous professionals for their helpful suggestions to improve the functionality and appearance of the UI.

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Hanley, B., Mitchell, C. I., Abbott, R. C., Hollingshead, N., Carstensen, M., Walsh, D., Christensen, S., Storm, D., Kelly, J., Them, C., Ahmed, M. S., Miller, L., & Schuler, K. 2021. *Regional Wildlife Disease Hazard Software* [Software]. Cornell University Library eCommons Repository. *https://doi.org/10.7298/hqg5-ac08*