Using Interactive Graphics to Visualize Evening Grosbeak Movement and Migration Patterns

Grace Bridge

Abstract

This project aims to analyze a large dataset on Evening Grosbeaks, a species within the finch family native to North America. The data comes from Motus, a network of radio receivers that are able to pick up transmissions from tagged birds. Motus has many large datasets of all types of bird species and through data cleaning in R, this project hones in on the data captured for Evening Grosbeaks. The main objective for this project was to develop a platform enabling users to observe and understand trends in their migration patterns. The R shiny app created for this showcases many features: an interactive map of deployment sites, individual bird tracking, group bird tracking (by winter roosting location and deployment location), all Evening Grosbeak data used, and all Evening Grosbeak data used from the Adirondack region. The app is available at: https://stlawu.shinyapps.io/evening_grosbeak_tracker/

Introduction

Evening Grosbeaks are an endangered species with a rapidly declining population. It is important to visualize their migration and movement patterns to then be able to analyze what is leading to their extinction.

The purpose of this project was to explore what tools from R Shiny can be used to for bird data visualizations and make raw data into an interactive, more accessible experience. The app provides users with a platform to interact with data, deployment sites, winter locations, individual trends, and group trends for the Evening Grosbeak.

Winter Spots and Breeding

For the Evening Grosbeak, it is important to look into their seasonal whereabouts. This may be a large aide in determining what is the cause of the rapidly declining population. This species is a very social species, who typically travel and roost in groups, especially in the winter.

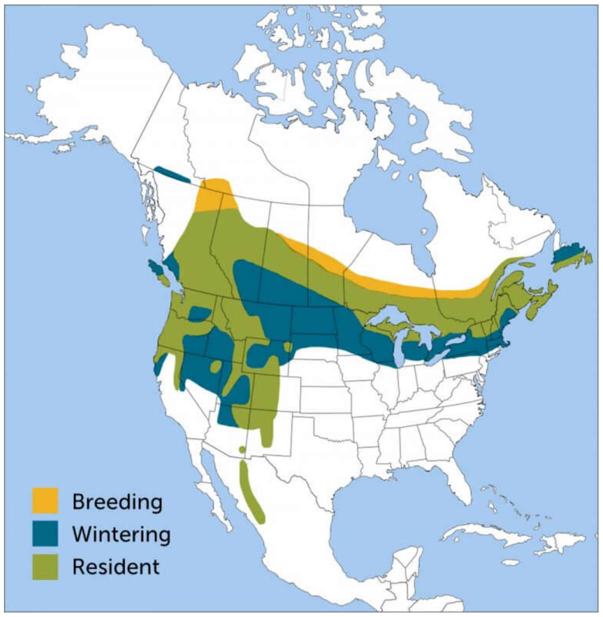


Figure 1: Evening Grosbeak Range Map

American Bird Conservatory

In the winter, the Evening Grosbeak searches for food. The bird's type of migration is called a "winter finch irruption," that is taken by many seed-eating birds. During these "irruptions," these birds move south of their typical breeding grounds in to find sources of winter food ("Evening Grosbeak").

Motus

Motus is a wildlife tracking system from Birds Canada. It is composed of a network of researchers around the world who are able to contribute to the radio telemetry system. By contributing (tagging birds and setting up radio receiver locations), more researchers are then able to access the growing database of bird tracking information ("About Motus"). While one researcher could hypothetically set up their own, small telemetry network to track a local bird, Motus creates the opportunity to connect all of these local sites and broaden data and information exponentially. Collaboration for scientists and bird-watchers across the world has been made easy by Motus.

For this application, access to a "project" was given by St. Lawrence biology professor, Dr. Susan Willson, who has a focus and interest in conservation of birds, namely the Evening Grosbeak. A "project" in Motus is an access point to the database with managed data access levels and users ("Motus").

Methods

R

R is an extremely popular language in the world of biodiversity conservation research for visualization and analyses. R is a cohesive set of software features and tools. It is also an open-source programming language. This means that it is free for use and collaboration. Anybody is able to create and add functions through writing packages to build upon existing operators and facilities for data, statistical analyses, visualizations, etc,. Work and research done in R is very often easily reproducible because R facilitates a space for creators to document their work cleanly and has a very readable structure. R files can be rendered in many ways (Word files, pdfs, webpages, etc.) to be shared and replicated ("What is R?").

Motus in R

One benefit of using Motus is its standardized data format across all projects. In addition to this, because of the large network of researchers, many analyses have been well documented and created already for Motus data usage. And so, the visualizations made and the data manipulation tools needed for this project were kick started by existing work with Motus in R.

Motus R Package

Birds Canada, the creator of the radio telemetry network of Motus, has detailed documentation for an R package to use the Motus data. The website for this package gives extensive instruction on how to get started using the Motus database in R, how to access data, how to make sense of tag and receiver deployments, how to clean the data, and examples of how to explore the data ("Motus").

The following is the provided code to install the package.

```r
# Use these commented lines to install the packages
# install.packages(c("motus", "motusData"),
#                  repos = c(birdscanada = 'https://birdscanada.r-universe.dev',
#                            CRAN = 'https://cloud.r-project.org'))

# Load the packages for use
library(motus)
library(motusData)
```

There are two types of detection databases that a user can access. One is a receiver database, comprised of every detection of registered tags at one receiver The second is a project database, comprised of every detection of specific or your registered tags across the entire Motus network. The latter was used for this project.

Once connected to the project, one can work with the data while connected to motus, but this will take lots of time and computer power. It is easier to download the data until the most recent detection, and then save as a .RDS file so that one can work faster with a local dataset as a flat dataframe.

The data has many variables with explanations taken from https://motuswts.github.io/motus/articles/03-accessing-data.html

Variable Descriptions

Variable	Description
activity	data related to radio activity for each hour period (hourBin) at each antenna, including a count of the number of short runs used in helping identify false detections.
admInfo	internal table used to keep track of your the motus package used to create your motus file, and the data version.
antDeps	metadata related to antenna deployments, e.g., deployment height, angle, antenna type.
batchRuns	metadata for runIDs and associated batchIDs
batches	detection data for a given receiver and boot number.
filters	metadata related to user created filters associated with the specified receiver.
gps	metadata related to Geographic Positioning System (GPS) position of receiver.
hits	detection data at the level of individual hits.
meta	metadata related to the project and datatype (tags vs. receivers) that are included in the .motus file
nodeData	data related to nodes by batchID and time (ts)
nodeDeps	metadata related to nodes
projAmbig	metadata related to what projects have ambiguous tag detections
projs	metadata related to projects, e.g., project name, principal investigator.
pulseCounts	number of radio pulses measured on each antenna over each hour period (hourBin).
recvDeps	metadata related to receiver deployments, e.g., deployment date, location, receiver characteristics.
recvs	metadata related to receiver serial number and associated Motus deviceID
runs	detection data associated with a run (continuous detections of a unique tag on a given receiver).
runsFilters	a list of runIDs associated with user created filters and assigned probabilities.
species	metadata related to species, e.g., unique identifier, scientific name, common name.
tagAmbig	metadata related to ambiguous tags, e.g., ambigID and associated motusTagID

Variable	Description
tagDeps	metadata related to tag deployments, e.g., deployment date, location, and species.
tagProp	metadata related to custom deployment properties entered by the principal investigator (e.g. body weight).
tags	metadata related to tags, e.g., unique identifier, tag characteristics (e.g., burst interval).
allambigs	lists in long-data format each motusTagID (up to 6) associated with each negative ambigID.
alltags	provides the full detection data for all tags, and all ambiguous (duplicate) tags, associated with your project. Ambiguous detections are repeated for each motusTagID represented by each ambigID.
alltagsGPS	same as alltags but includes GPS latitude, longitude and altitude (much slower to load on large databases).

Data Cleaning

Once the data from the .motus is made into a flat data frame, data can be cleaned. The first step was to trim the exhaustive project data down to just the Evening Grosbeak.

```r
# filter to only Evening Grosbeak
df <- tbl.alltags %>%
  filter(speciesID == 20570) %>%   # Evening Grosbeak Species ID
  collect() %>%
  as.data.frame() %>%
  mutate(time = as_datetime(ts))
# This also changes ts to a date variable instead of numeric (how it was read in)
```

From the data, it is also important to be able to grab a unique bird. A unique tag (either motusTagID or tagDeployID) is not quite capable of this. This is because, a unique motusTagID is not always a unique bird; occasionally a tag can be redeployed onto a different bird. Also a tagDeployID is not always unique when you are focusing on a specific deployment of a bird in your project. So, use a combination of these ("Motus").

```r
df <- df_alltags %>%
  mutate(motusTagDepID = paste(motusTagID, tagDeployID, sep = "."))
```

Here is how the new variable would look:

motusTagID	tagDeployID	motusTagDepID	recvDeployLat	recvDeployLon	ts
45833	31743	45833.31743	41.5017	-79.0798	2021-01-24 13:58:45

Now, we can grab the data for any single bird's deployment with motusTagDepID.

R Shiny

Shiny is an R package (extension to R, standardized tools with documentation that can be installed to your machine). Once installed, this package creates the opportunity for application construction. The code for these apps have three components, the UI (user-interface object), the server function, and a final call to the shinyApp function. The UI draws up the appearance of the app; what the user is seeing. The server function is responsible for the code that performs the outputs and their functionalities. And the final call to the shinyApp function will launch the app when the code is ran ("Welcome to Shiny").

There are many benefits to using Shiny to showcase data analyses and visualizations. To start, the interactive ability of a Shiny app can transform user accessibility to data. With these apps, there are many widgets that the creator can include in the UI (that then speak to the server output) that allows a user to choose what they are seeing from the data: slider inputs (for numerical input), text inputs, checkboxes, dropdown menus, file uploaders, etc. With this user power to choose outputs, Shiny apps can be reactive and responsive, updating the outputs of each page in real-time. Another benefit is ease of deployment for Shiny apps. Instead of code files or papers portraying research, Shiny apps can be deployed easily with URLS and showcase findings in a more fluid, interactive, and engaging way ("Welcome to Shiny").

The following is the starting structure for a Shiny App in R:

```r
#
# This is a Shiny web application. You can run the application by clicking
# the 'Run App' button above.
#
# Find out more about building applications with Shiny here:
#
#    http://shiny.rstudio.com/
#

library(shiny)

# Define UI for application that draws a histogram
ui <- fluidPage(
    # Application title
    titlePanel("Old Faithful Geyser Data"),

    # Sidebar with a slider input for number of bins
    sidebarLayout(
        sidebarPanel(
            sliderInput("bins",
                        "Number of bins:",
                        min = 1,
                        max = 50,
                        value = 30)
        ),

        # Show a plot of the generated distribution
        mainPanel(
           plotOutput("distPlot")
        )
    )
)

# Define server logic required to draw a histogram
server <- function(input, output) {

    output$distPlot <- renderPlot({
        # generate bins based on input$bins from ui.R
        x    <- faithful[, 2]
        bins <- seq(min(x), max(x), length.out = input$bins + 1)

        # draw the histogram with the specified number of bins
        hist(x, breaks = bins, col = 'darkgray', border = 'white',
             xlab = 'Waiting time to next eruption (in mins)',
             main = 'Histogram of waiting times')
    })
}

# Run the application
shinyApp(ui = ui, server = server)
```

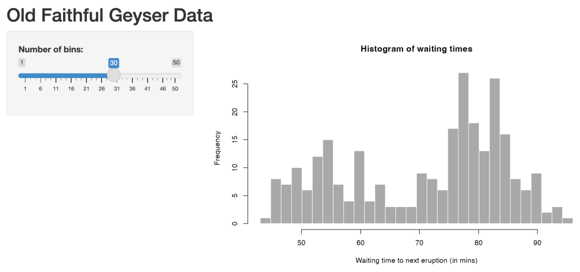

Old Faithful Geyser Data
Number of bins:
Histogram of waiting times
Frequency
Waiting time to next eruption (in mins)

Figure 2: Default Shiny App

We can see here that this app has an option in the UI for sliderInput where the user can control the number of bins in the histogram. As the user interacts with this widget, the number of bins on the histogram is changed by the server's response and generation of output for this input.

Next is an example of a dropdown menu (using the IRIS dataset: a popular example dataset about iris dimensions).

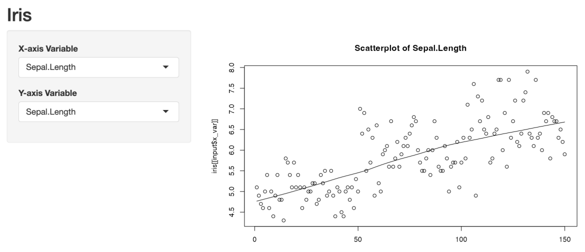
```r
library(shiny)

ui <- fluidPage(
  titlePanel("Iris"),
  sidebarLayout(
    sidebarPanel(
      selectInput("x_var", "X-axis Variable", choices = c("Sepal.Length", "Sepal.Width", "Pe
      selectInput("y_var", "Y-axis Variable", choices = c("Sepal.Length", "Sepal.Width", "Pe
    ),
    mainPanel(
      plotOutput("histogram")
    )
  )
)

server <- function(input, output) {

  output$histogram <- renderPlot({
    summary(iris[[input$x_var]])
    scatter.smooth(iris[[input$x_var]], main = paste("Scatterplot of", input$x_var))
  })
}

shinyApp(ui = ui, server = server)
```

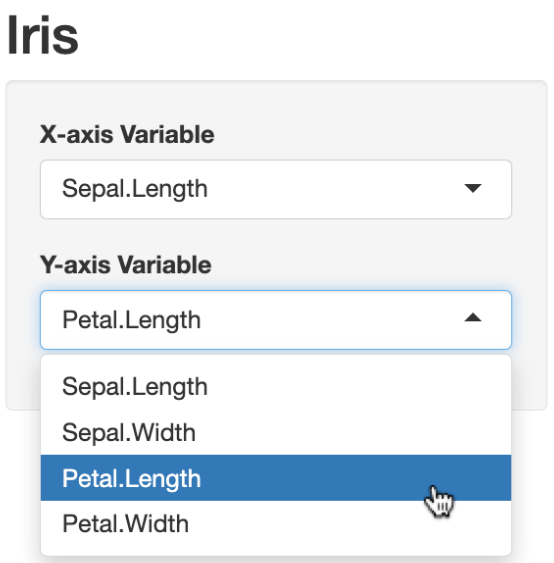

Iris

X-axis Variable

Sepal.Length

Y-axis Variable

Sepal.Length


Iris

X-axis Variable

Sepal.Length

Y-axis Variable

Petal.Length

Leaflet

Leaflet is another package for data visualizations in R. It comes from a JavaScript library for interactive maps. With this package, one can customize maps with different markers, shadings, pop-ups, lines, and more. This is a very popular tool that pairs well with the R software for exploring spatial data ("An R Interface to Leaflet").

Below is a basic example of creating a leaflet map.

```r
library(leaflet)

map <- leaflet() %>%
  setView(lat = 44.5956, lng = -75.1691, zoom = 13) %>%  # Setting initial view to London
  addTiles()  # Add default OpenStreetMap tiles

map
```

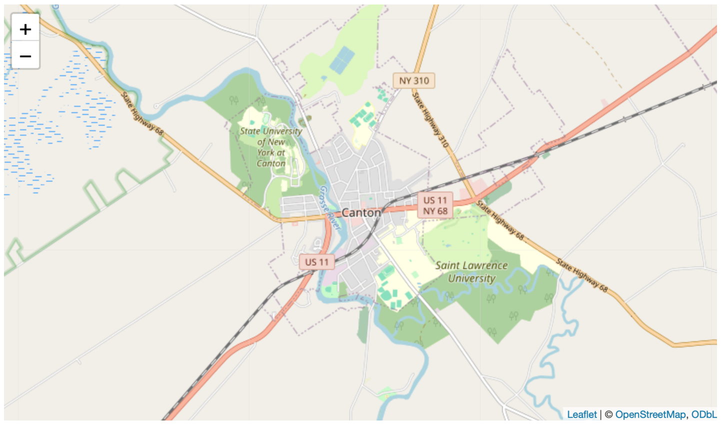
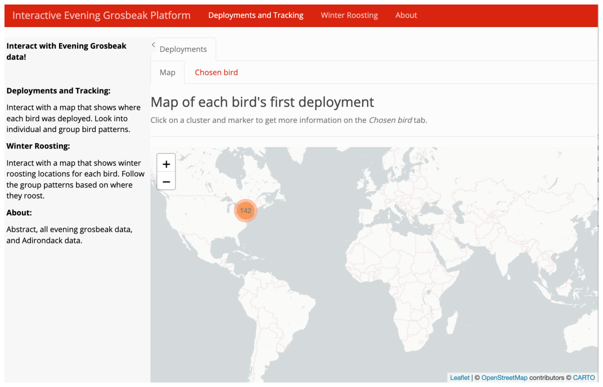

NY 310
State Highway 310
State Highway 68
State University of New York at Canton
Canton
US 11
NY 68
US 11
Saint Lawrence University
State Highway 68
State Highway 68
Leaflet | © OpenStreetMap, ODbL

Figure 3: Leaflet map

Shiny App Results

The interactive Evening Grosbeak platform was made using Shiny in R. From the navigation bar, the user can choose from "Deployments and Tracking," "Winter Roosting," or "About." Each navigation page includes multiple tabs for exploration.


Interactive Evening Grosbeak Platform
Deployments and Tracking
Winter Roosting
About
Deployments
Map
Chosen bird
142
Leaflet | © OpenStreetMap contributors © CARTO

Interact with Evening Grosbeak data!

Deployments and Tracking:

Interact with a map that shows where each bird was deployed. Look into individual and group bird patterns.

Winter Roosting:

Interact with a map that shows winter roosting locations for each bird. Follow the group patterns based on where they roost.

About:

Abstract, all evening grosbeak data, and Adirondack data.

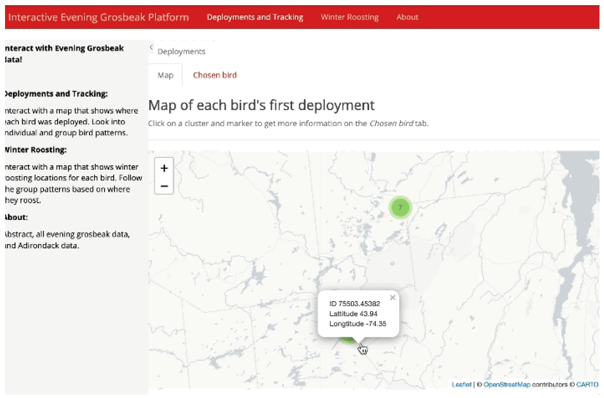
Map of each bird's first deployment

Click on a cluster and marker to get more information on the *Chosen bird* tab.

Figure 4: Interactive Evening Grosbeak Platform

Deployments and Tracking

Upon launching the app, the user is met with the Deployments and Tracking page. This page first includes the leaflet map of each bird's first deployment.The user can click through the map of different clusters until they find a specific bird at a deployment site that they want to look further into. Upon clicking on this circle marker, the app grabs the data for this bird and stores it to use in the next tab.


Interactive Evening Grosbeak Platform
Deployments and Tracking
Winter Roosting
About
Deployments
Map
Chosen bird
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Leaflet | © OpenStreetMap contributors © CARTO

nteract with Evening Grosbeak
lata!

Deployments and Tracking:

nteract with a map that shows where
each bird was deployed. Look into
ndividual and group bird patterns.

Winter Roosting:

nteract with a map that shows winter
oosting locations for each bird. Follow
he group patterns based on where
hey roost.

About:

Abstract, all evening grosbeak data,
and Adirondack data.

Map of each bird's first deployment

Click on a cluster and marker to get more information on the *Chosen bird* tab.

ID 75503.45382
Lattitude 43.94
Longtitude -74.35

Figure 5: Deployments map

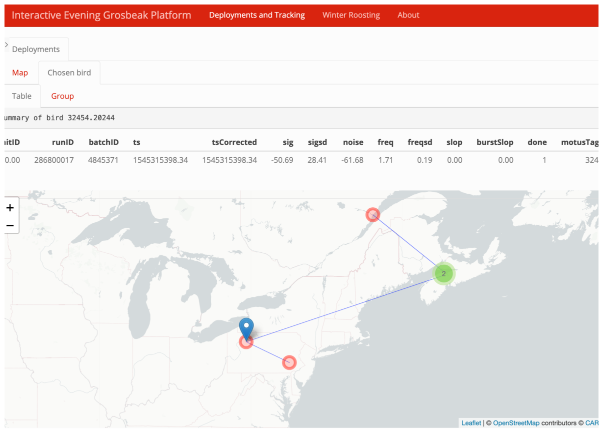
```
output$map <- renderLeaflet({
      leaflet() %>%
        addProviderTiles(providers$CartoDB.PositronNoLabels) %>%
        setView(lat = 15, lng = 0, zoom = 1.5)
    })

# Render circle markers
observe({
  map <- leafletProxy("map", data = mapDATA())
  map %>% clearMarkers()
  if (!is.null(mapDATA())) {
    map %>%
      addCircleMarkers(lat = ~tagDepLat,
                       lng = ~tagDepLon,
                       layerId = ~motusTagDepID,
                       clusterOptions =  markerClusterOptions()
      )
  }
})

# Show popup on click
observeEvent(input$map_marker_click, {
  click <- input$map_marker_click
  text<-paste("ID", click$id, "<br>Lattitude ", round(click$lat, 2), "<br>Longtitude ", round

  map <- leafletProxy("map")
  map %>% clearPopups() %>%
    addPopups(click$lng, click$lat, text)
})
```

The next tab is the Chosen bird tab. In the Table nested tab: first, we have a page that shows the immediate data for the bird that was chosen from its deployment, then we have a map of the locations where this bird has pinged a receiver. In the Group nested tab we have a similar map, but it shows the pings for each of the birds deployed from the same deployment site. The lines are weighted by the frequency of the amount of birds that traveled there.


Interactive Evening Grosbeak Platform
Deployments and Tracking
Winter Roosting
About
Deployments
Map
Chosen bird
Table
Group
+
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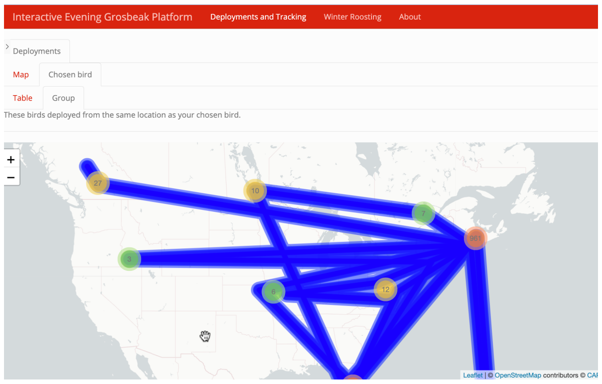
```
ummary of bird 32454.20244
```

itID	runID	batchID	ts	tsCorrected	sig	sigsd	noise	freq	freqsd	slop	burstSlop	done	motusTag
0.00	286800017	4845371	1545315398.34	1545315398.34	-50.69	28.41	-61.68	1.71	0.19	0.00	0.00	1	324

Figure 6: Chosen bird map

```r
output$Click_plot <- renderLeaflet({
  click <- input$map_marker_click
  if (!is.null(click)){
    bird <- DATA[which(DATA$motusTagDepID == click$id), ]

    # Go through full data set now to check for this bird with matching id
    one_bird <- eg_df %>%
      filter(eg_df$motusTagDepID == bird$motusTagDepID)

    # sort one_bird by timestamp to ensure you are getting very first pinpoint
    one_bird <- one_bird %>%
      arrange(tsCorrected)
    firstDep <- one_bird %>%
      slice(1)

    # firstDep uses deployment coordinates to mark
    # one_bird uses receiver coordinates to mark
    one_bird <- one_bird[-1, ] # take out deployment site (initial point and point of firstDe
    # # rename lat and long for each data set
    firstDep <- firstDep %>%
      rename(
        lat = tagDepLat,
        lon = tagDepLon,
      )
    one_bird <- one_bird %>%
      rename(
        lat = recvDeployLat,
        lon = recvDeployLon
      )
    # join the data sets (vertically) (first row should be deploymnent site)
    # make copies of datasets with desired data
    firstDepCopy <- firstDep %>%
      select(motusTagDepID, lat, lon, tsCorrected, ts)
    one_birdCopy <- one_bird %>%
      select(motusTagDepID, lat, lon, tsCorrected, ts)
    full_bird <- bind_rows(firstDepCopy, one_birdCopy)

    new_full_bird <- full_bird %>%
      group_by(lat, lon) %>%
      slice(1)

    popupInfo = paste("Lat = ", new_full_bird$lat, ", Lon = ", new_full_bird$lon)


    leaflet() %>%
      addProviderTiles(providers$CartoDB.PositronNoLabels) %>%
      setView(lat = 15, lng = 0, zoom = 1.5) %>%
      addAwesomeMarkers(data = firstDep,
                        lng = ~lon,
                        lat = ~lat) %>%
      addCircleMarkers(data = new_full_bird,
                       lng = ~lon,
                       lat = ~lat,
                       color = "red",
                       popup = popupInfo,
                       clusterOptions = markerClusterOptions()) %>%
      addPolylines(data = new_full_bird,
                   lng = ~lon,
                   lat = ~lat,
                   color ="blue",
                   weight = 1)
  }
})
```

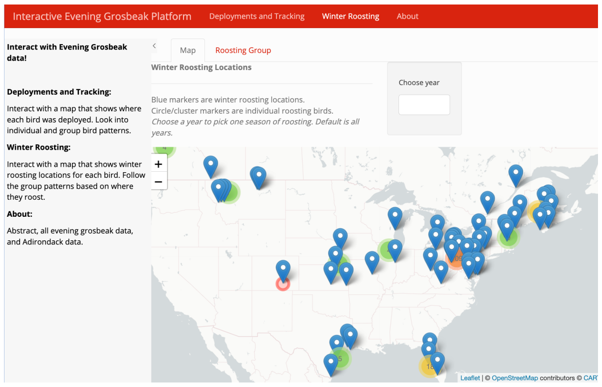

Interactive Evening Grosbeak Platform
Deployments and Tracking
Winter Roosting
About
Deployments
Map
Chosen bird
Table
Group
+
−
Leaflet | © OpenStreetMap contributors © CAR

These birds deployed from the same location as your chosen bird.

Figure 7: Chosen group map

Winter Roosting

The next page is the Winter Roosting page. On the first tab of this page, Map, there is a leaflet map. The blue markers are of each winter location that birds have roosted. The circle and cluster markers are for the individual birds who spent the winter there. The user can choose which year of winter they want to look at (the months defined for winter roosting for this application are January, February, and December) and the default is all years. On the second tab of this page, Roosting Group, there is another leaflet map which tracks the birds from the same roosting location based on year and location.


Interactive Evening Grosbeak Platform
Deployments and Tracking
Winter Roosting
About
Map
Roosting Group
Choose year
+
−
Leaflet | © OpenStreetMap contributors © CAR

Interact with Evening Grosbeak data!

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Winter Roosting:

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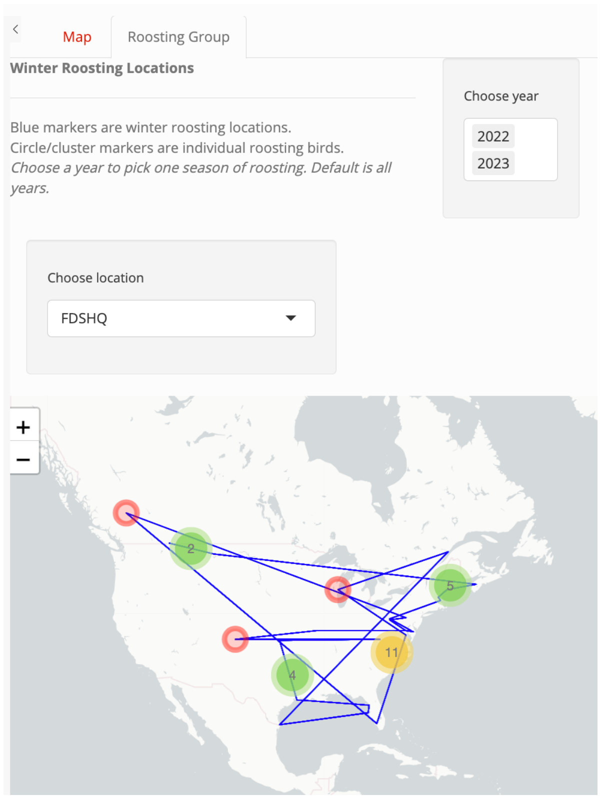
About:

Abstract, all evening grosbeak data, and Adirondack data.

Winter Roosting Locations

Blue markers are winter roosting locations.
Circle/cluster markers are individual roosting birds.
Choose a year to pick one season of roosting. Default is all years.

Figure 8: Winter roosting location map



Winter Roosting Locations

Blue markers are winter roosting locations.
Circle/cluster markers are individual roosting birds.
Choose a year to pick one season of roosting. Default is all years.

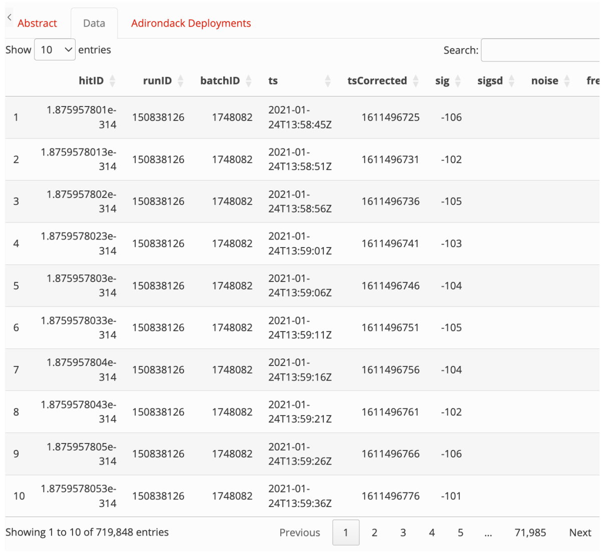
Choose year
2022
2023

Choose location
FDSHQ

Figure 9: Winter roosting group map

About

The About includes page includes three tabs: Abstract, Data, and Adirondack Deployments. The tab simply includes the abstract for this project. The Data tab includes a data table for all of the Evening Grosbeak data used for these visualizations. The Adirondack Deployments tab includes a data table specifically for all of the Evening Grosbeak data from birds that were deployed from the Adirondack Region.



	hitID	runID	batchID	ts	tsCorrected	sig	sigsd	noise	fre
1	1.875957801e-314	150838126	1748082	2021-01-24T13:58:45Z	1611496725	-106			
2	1.8759578013e-314	150838126	1748082	2021-01-24T13:58:51Z	1611496731	-102			
3	1.875957802e-314	150838126	1748082	2021-01-24T13:58:56Z	1611496736	-105			
4	1.8759578023e-314	150838126	1748082	2021-01-24T13:59:01Z	1611496741	-103			
5	1.875957803e-314	150838126	1748082	2021-01-24T13:59:06Z	1611496746	-104			
6	1.8759578033e-314	150838126	1748082	2021-01-24T13:59:11Z	1611496751	-105			
7	1.875957804e-314	150838126	1748082	2021-01-24T13:59:16Z	1611496756	-104			
8	1.8759578043e-314	150838126	1748082	2021-01-24T13:59:21Z	1611496761	-102			
9	1.875957805e-314	150838126	1748082	2021-01-24T13:59:26Z	1611496766	-106			
10	1.8759578053e-314	150838126	1748082	2021-01-24T13:59:36Z	1611496776	-101			

Showing 1 to 10 of 719,848 entries

Figure 10: Data table page

Discussion

Obstacles

Creating the Shiny App for this large dataset provided many hurdles with data manipulation and programming. One problem occurred with Shiny and reactive data. For the deployments page, the cluster/circle markers for each bird will only show up if this ta comes absolutely first in the app structure. This was a problem as we wanted to restructure the app and have the interactive deployments map later, but we had to leave it first to keep our data displayed. Another problem was also related to the reactive data on the deployments page: no other tab could have this type of reactive data that was observing events. On the deployments map, as a user clicks on a marker, the app observes this event and stores the data for the next tab. The original plan was to have a similar mechanism for the winter roosting locations map. But, when attempting to make observable clicks on this map, the deployments map data would disappear. The intended mechanism for this was replaced in the winter groups map by adding a dropdown menu for location: not quite as fluid, but still makes it possible for a user to look through the routes of a specific wintering group.

Future and Improvements

A main goal of this project was to create a platform that can be expanded upon. This is a great base for a future student with the knowledge, background, and tools to improve on the features, create more visualizations, and analyze the patterns of the birds. Advanced versions of these visualizations in the hands of the right student researcher will be able to lead them to a conclusion about why the Evening Grosbeak population is declining so rapidly.

Some suggestions for improvement on this app are the following. Upon further research of the Evening Grosbeak habitats, sift through the data and take out faulty data (such as the birds showing up in South America when they should not be). Use the plots provided to discover more data that may not be accurate. Also, add features to see the bird's routes over a specific timeline. This could be done with a sliderInput (over time) to pick a specific time period (possibly from winter roosting to breeding, or summer to summer).

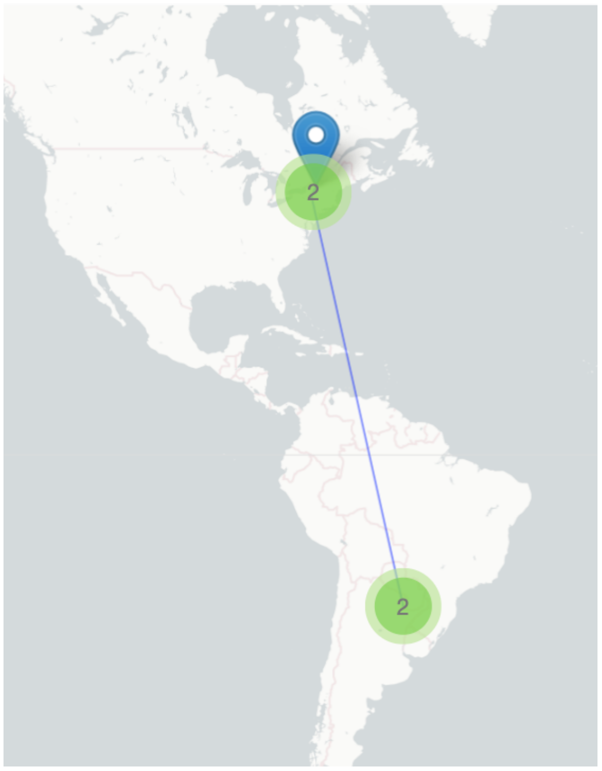


Figure 11: Bird 75503.45382

Conclusion

Creating this interactive platform has transformed my data science knowledge and has blended together many of the coursework topics I have spent years learning. I have been able to expand on my previous knowledge of data cleaning and manipulation when working with this spatial data, which is not a type of data I have gotten the chance to work with before. Working with leaflet has broadened my understanding on the possibilities of data visualizations within R. Working with a large dataset effectively has brought me many tools that will be necessary for working with impactful data and making it accessible to others.

Acknowledgements

I would like to thank Dr. Ivan Ramler for his support and guidance throughout this project. I would also like to thank Dr. Susan Willson for the motivation behind this project.

References

- “About Motus.” Motus. https://motus.org/about/. Accessed 11 May 2024.
- “An R Interface to Leaflet Maps.” Leaflet. https://rstudio.github.io/leaflet/. Accessed 11 May 2024.
- “Evening Grosbeak.” CornellLab https://www.allaboutbirds.org/guide/Evening_Grosbeak/id. Accessed 11 May 2024.
- “Motus.” Motus. https://motuswts.github.io/motus/index.html. Accessed 11 May 2024.
- “Welcome to Shiny.” Shiny https://shiny.posit.co/r/getstarted/shiny-basics/lesson1/index.html. Accessed 11 May 2024.
- “What is R?.” R Project. https://www.r-project.org/about.html. Accessed 11 May 2024.