Exploring bee-related spatial data

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Conservation/ecology Topics

- Species distributions

Computational Topics

- Convert a data frame to a spatial object.
- Plot multiple spatial layers.

Lab part 1: Oregon bee atlas data exploration

a. Import the OBA data.

```
oba <- read.csv("OBA_2018-2023.csv")
head(oba)
```

```
##                   Observation.No. Voucher.No. user_id     user_login
## 1 Andony_Melathopoulos:18.001.001              429964 amelathopoulos
## 2 Andony_Melathopoulos:18.002.001              429964 amelathopoulos
## 3 Andony_Melathopoulos:18.002.002              429964 amelathopoulos
## 4 Andony_Melathopoulos:18.002.003              429964 amelathopoulos
## 5 Andony_Melathopoulos:18.002.004              429964 amelathopoulos
## 6 Andony_Melathopoulos:18.002.005              429964 amelathopoulos
##   Collector...First.Name Collector...First.Initial Collector...Last.Name
## 1                 Andony                         A.          Melathopoulos
## 2                 Andony                         A.          Melathopoulos
## 3                 Andony                         A.          Melathopoulos
## 4                 Andony                         A.          Melathopoulos
## 5                 Andony                         A.          Melathopoulos
## 6                 Andony                         A.          Melathopoulos
##        Collectors taxon_kingdom_name Associated.plant...genus..species url
## 1 A.Melathopoulos
## 2 A.Melathopoulos
## 3 A.Melathopoulos
## 4 A.Melathopoulos
## 5 A.Melathopoulos
## 6 A.Melathopoulos
```

```
##   Sample.ID Specimen.ID Collection.Day.1 Month.1  MonthJul MonthAb Year.1
## 1                   NA               18     iii     March       3   2018
## 2                   NA               20     iii     March       3   2018
## 3                   NA               20     iii     March       3   2018
## 4                   NA               20     iii     March       3   2018
## 5                   NA                2      ix September       9   2018
## 6                   NA                2      ix September       9   2018
##   Collection.Date Time.1 Collection.Day.2 Month.2 Year.2 Collection.Day.2.Merge
## 1       3/18/2018
## 2       3/20/2018
## 3       3/20/2018
## 4       3/20/2018
## 5        9/2/2018
## 6        9/2/2018
##   Time.2    Collection.ID Position.of.1st.digit Collection.No. Sample.No.
## 1        A Melathopoulos                                   1          1
## 2         A Melathopoulos                                  2          1
## 3         A Melathopoulos                                  2          2
## 4         A Melathopoulos                                  2          3
## 5         A Melathopoulos                                  2          4
## 6         A Melathopoulos                                  2          5
##   Country  State  County                                    Location
## 1     USA Oregon  Benton                      Corvallis, NW Orchard Ave
## 2     USA Oregon  Benton                      Corvallis, NW Orchard Ave
## 3     USA Oregon  Benton                      Corvallis, NW Orchard Ave
## 4     USA Oregon  Benton                      Corvallis, NW Orchard Ave
## 5     USA Oregon Clatsop Clatskanie, Big Creek Mainline, Knob Point Road
## 6     USA Oregon Clatsop Clatskanie, Big Creek Mainline, Knob Point Road
##           Abbreviated.Location Collection.Site.Description          Team
## 1    Astoria Maggie Johnson Rd                              Melathopoulos
## 2 Big Crk. Mainline Knob Pt Rd                              Melathopoulos
## 3 Big Crk. Mainline Knob Pt Rd                              Melathopoulos
## 4 Big Crk. Mainline Knob Pt Rd                              Melathopoulos
## 5 Big Crk. Mainline Knob Pt Rd                              Melathopoulos
## 6 Big Crk. Mainline Knob Pt Rd                              Melathopoulos
##   Habitat Elevation..m. Dec..Lat. Dec..Long.  X Collectionmethod
## 1                        44.556   -123.285 NA              Net
## 2                        44.567   -123.283 NA              Net
## 3                        44.567   -123.283 NA              Net
## 4                        44.567   -123.283 NA              Net
## 5                        46.102   -123.506 NA              Net
## 6                        46.102   -123.506 NA              Net
##   Collection.method.merge.field Associated.plant...family
## 1
## 2
## 3
## 4
## 5
## 6
##   Associated.plant...genus..species.1 Associated.plant...Inaturalist.URL
## 1
## 2
## 3
## 4
```

```
## 5
## 6
##   Associated.plant Assoc.plant.merge.field          Collectors.1
## 1                                          Andony Melathopoulos
## 2                                          Andony Melathopoulos
## 3                                          Andony Melathopoulos
## 4                                          Andony Melathopoulos
## 5                                         Andony Melathopoulos
## 6                                         Andony Melathopoulos
##   Collector.1.abreviation Collector.2 Collector.3 Genus Species sex caste
## 1        A Melathopoulos           NA          NA
## 2         A Melathopoulos          NA          NA
## 3         A Melathopoulos          NA          NA
## 4         A Melathopoulos          NA          NA
## 5         A Melathopoulos          NA          NA
## 6         A Melathopoulos          NA          NA
##   vol.det.Genus vol.det.Species vol.det.sex.caste Determined.By Date.Determined
## 1                                                                            NA
## 2                                                                            NA
## 3                                                                            NA
## 4                                                                            NA
## 5                                                                            NA
## 6                                                                            NA
##   Verified.By Other.Determiner.s. Other.Dets.Sci..Name.s. Other.Dets..Date.s.
## 1          NA                                         NA                  NA
## 2          NA                                         NA                  NA
## 3          NA                                         NA                  NA
## 4          NA                                         NA                  NA
## 5          NA                                         NA                  NA
## 6          NA                                         NA                  NA
##   Additional.Notes X.1
## 1                   NA
## 2                   NA
## 3                   NA
## 4                   NA
## 5                   NA
## 6                   NA
```

b. Find the columns related to genus and species and paste them together (with a space between) using the function paste(). Name the new column GenusSpecies.

```
oba$GenusSpecies = paste(oba$Genus, " ", oba$Species)
head(oba)
```

```
##                   Observation.No. Voucher.No. user_id     user_login
## 1 Andony_Melathopoulos:18.001.001              429964 amelathopoulos
## 2 Andony_Melathopoulos:18.002.001              429964 amelathopoulos
## 3 Andony_Melathopoulos:18.002.002              429964 amelathopoulos
## 4 Andony_Melathopoulos:18.002.003              429964 amelathopoulos
## 5 Andony_Melathopoulos:18.002.004              429964 amelathopoulos
## 6 Andony_Melathopoulos:18.002.005              429964 amelathopoulos
##   Collector...First.Name Collector...First.Initial Collector...Last.Name
## 1                 Andony                        A.         Melathopoulos
```

```
## 2                 Andony                          A.         Melathopoulos
## 3                 Andony                          A.         Melathopoulos
## 4                 Andony                          A.         Melathopoulos
## 5                 Andony                          A.         Melathopoulos
## 6                 Andony                          A.         Melathopoulos
##       Collectors taxon_kingdom_name Associated.plant...genus..species url
## 1 A.Melathopoulos
## 2 A.Melathopoulos
## 3 A.Melathopoulos
## 4 A.Melathopoulos
## 5 A.Melathopoulos
## 6 A.Melathopoulos
##   Sample.ID Specimen.ID Collection.Day.1 Month.1  MonthJul MonthAb Year.1
## 1                   NA               18     iii     March       3   2018
## 2                   NA               20     iii     March       3   2018
## 3                   NA               20     iii     March       3   2018
## 4                   NA               20     iii     March       3   2018
## 5                   NA                2      ix September       9   2018
## 6                   NA                2      ix September       9   2018
##   Collection.Date Time.1 Collection.Day.2 Month.2 Year.2 Collection.Day.2.Merge
## 1       3/18/2018
## 2       3/20/2018
## 3       3/20/2018
## 4       3/20/2018
## 5        9/2/2018
## 6        9/2/2018
##   Time.2    Collection.ID Position.of.1st.digit Collection.No. Sample.No.
## 1        A Melathopoulos                                    1          1
## 2         A Melathopoulos                                   2          1
## 3         A Melathopoulos                                   2          2
## 4         A Melathopoulos                                   2          3
## 5         A Melathopoulos                                   2          4
## 6         A Melathopoulos                                   2          5
##   Country  State  County                                        Location
## 1     USA Oregon  Benton                      Corvallis, NW Orchard Ave
## 2     USA Oregon  Benton                      Corvallis, NW Orchard Ave
## 3     USA Oregon  Benton                      Corvallis, NW Orchard Ave
## 4     USA Oregon  Benton                      Corvallis, NW Orchard Ave
## 5     USA Oregon Clatsop Clatskanie, Big Creek Mainline, Knob Point Road
## 6     USA Oregon Clatsop Clatskanie, Big Creek Mainline, Knob Point Road
##           Abbreviated.Location Collection.Site.Description          Team
## 1    Astoria Maggie Johnson Rd                              Melathopoulos
## 2 Big Crk. Mainline Knob Pt Rd                              Melathopoulos
## 3 Big Crk. Mainline Knob Pt Rd                              Melathopoulos
## 4 Big Crk. Mainline Knob Pt Rd                              Melathopoulos
## 5 Big Crk. Mainline Knob Pt Rd                              Melathopoulos
## 6 Big Crk. Mainline Knob Pt Rd                              Melathopoulos
##   Habitat Elevation..m. Dec..Lat. Dec..Long.  X Collectionmethod
## 1                       44.556   -123.285 NA              Net
## 2                       44.567   -123.283 NA              Net
## 3                       44.567   -123.283 NA              Net
## 4                       44.567   -123.283 NA              Net
## 5                       46.102   -123.506 NA              Net
## 6                       46.102   -123.506 NA              Net
```

```
##   Collection.method.merge.field Associated.plant...family
## 1
## 2
## 3
## 4
## 5
## 6
##   Associated.plant...genus..species.1 Associated.plant...Inaturalist.URL
## 1
## 2
## 3
## 4
## 5
## 6
##   Associated.plant Assoc.plant.merge.field          Collectors.1
## 1                                          Andony Melathopoulos
## 2                                          Andony Melathopoulos
## 3                                          Andony Melathopoulos
## 4                                          Andony Melathopoulos
## 5                                         Andony Melathopoulos
## 6                                         Andony Melathopoulos
##   Collector.1.abreviation Collector.2 Collector.3 Genus Species sex caste
## 1        A Melathopoulos           NA          NA
## 2         A Melathopoulos          NA          NA
## 3         A Melathopoulos          NA          NA
## 4         A Melathopoulos          NA          NA
## 5         A Melathopoulos          NA          NA
## 6         A Melathopoulos          NA          NA
##   vol.det.Genus vol.det.Species vol.det.sex.caste Determined.By Date.Determined
## 1                                                                            NA
## 2                                                                            NA
## 3                                                                            NA
## 4                                                                            NA
## 5                                                                            NA
## 6                                                                            NA
##   Verified.By Other.Determiner.s. Other.Dets.Sci..Name.s. Other.Dets..Date.s.
## 1          NA                                         NA                  NA
## 2          NA                                         NA                  NA
## 3          NA                                         NA                  NA
## 4          NA                                         NA                  NA
## 5          NA                                         NA                  NA
## 6          NA                                         NA                  NA
##   Additional.Notes X.1 GenusSpecies
## 1                  NA
## 2                  NA
## 3                  NA
## 4                  NA
## 5                  NA
## 6                  NA
```

c. Use `sort()` and `unique()` to print the unique values of GenusSpecies in alphabetical order. How many species are there?

```
length(unique(sort(oba$GenusSpecies)))
```

```
## [1] 539
```

Some specimens are not identified to species, only genus. How is this reflected in the data? In two weeks we will learn how to clean this up using regular expressions.

d. So many bees, so little time. Count up the occurrences of each bee species, and subset the data to bees that have been seen at least two times. You can use the tidyverse or any other functions in R that you like. How many "species" are there?

```
species_count <- oba %>%
  group_by(Species) %>%
  filter(n() >= 2)

num_species <- length(unique(species_count$Species))
num_species
```

```
## [1] 346
```

e. Google a few bee names (that have been seen > 2 times) and find one with an a look that resonates with you.

What is the name of your bee? I like the Longula bee species :)

Import the photos into Rmarkdown below (hint: googling bee name "discover life" or "inat" can often get you a photo. Many bees will no have any photos :(

Lab part 2: Plotting the distrubution of your spirit bee.

How that have chosen your spirit bee, we would like to plot it's distribution. What is the crs of the data? Annoyingly it is not described anywhere in the spreadsheet (always list your crs in your data) but it is the same as what inat uses because all bees have a georeferenced plant host. If the data is in lat long, it is "unprojected" so only a datum will be listed. DATUM: WGS84, unprojected lat long. EPSG code: 4326.

```
crs("EPSG:4326")
```

```
## [1] "GEOGCRS[\"WGS 84\",\n    ENSEMBLE[\"World Geodetic System 1984 ensemble\",\n        MEMBER[\"Wo
```

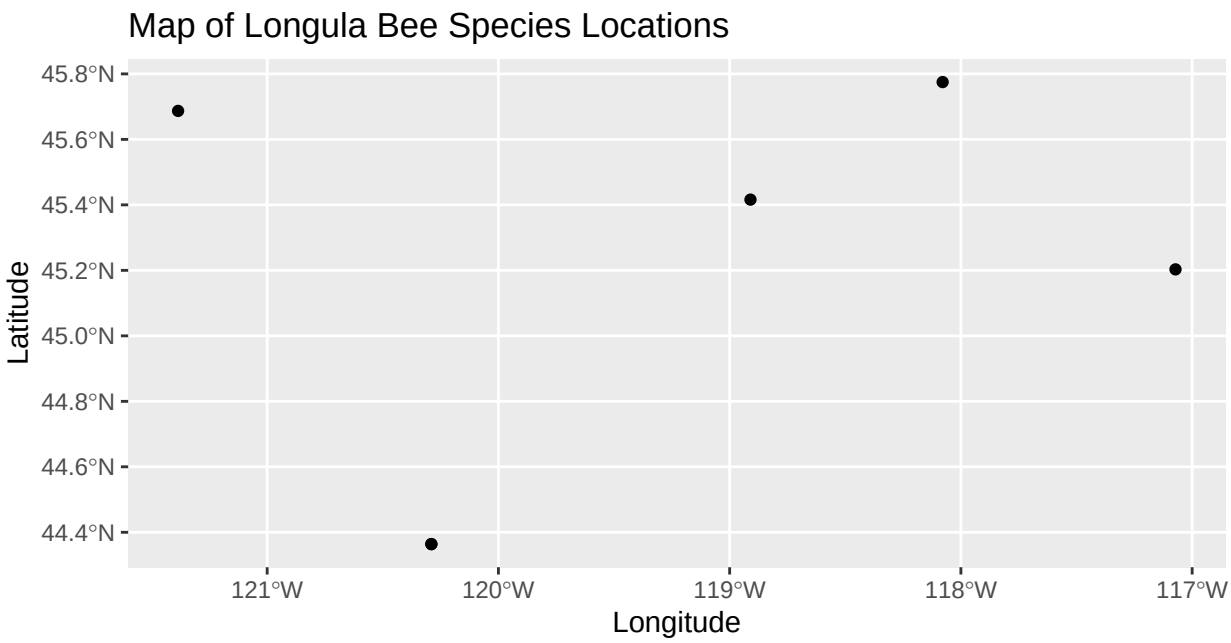
a. Extract the X and Y locations for your species only from the data and create a spatial object. Don't forget to set the CRS! Hint 1: consider what other data you would like to keep as attributes, for example what flower they were foraging on. Hint 2: Remember the lat is y and long is x. Hint 3: You may want to rename the column names you can use, colnames() and reassign the names, since the ones in the oba data spreadsheet are really ugly.

```
spirit_bee_data <- oba %>%
  filter(Species == "longula") %>%
  select(Species, Associated.plant, Dec..Long., Dec..Lat., Collection.Date)

colnames(spirit_bee_data) <- c("Species", "Flower", "X", "Y", "Date Collected")

spirit_bee_sf <- st_as_sf(spirit_bee_data, coords = c("X", "Y"), crs = crs("EPSG:4326"))

head(spirit_bee_sf)
```

```
## Simple feature collection with 6 features and 3 fields
## Geometry type: POINT
## Dimension:     XY
## Bounding box:  xmin: -121.3852 ymin: 44.364 xmax: -117.072 ymax: 45.775
## Geodetic CRS:  WGS 84
##   Species          Flower Date Collected                 geometry
## 1 longula Vicia americana       6/2/2018   POINT (-120.29 44.364)
## 2 longula Vicia americana       6/2/2018   POINT (-120.29 44.364)
## 3 longula                      5/17/2018 POINT (-121.3852 45.687)
## 4 longula                      6/19/2019  POINT (-117.072 45.203)
## 5 longula                       5/8/2019   POINT (-118.91 45.416)
## 6 longula                      6/12/2019  POINT (-118.079 45.775)
```

b. Plot your exciting bee data!

```
ggplot() +
  geom_sf(data = spirit_bee_sf) +
  ggtitle("Map of Longula Bee Species Locations") +
  labs(x = "Longitude", y = "Latitude")
```



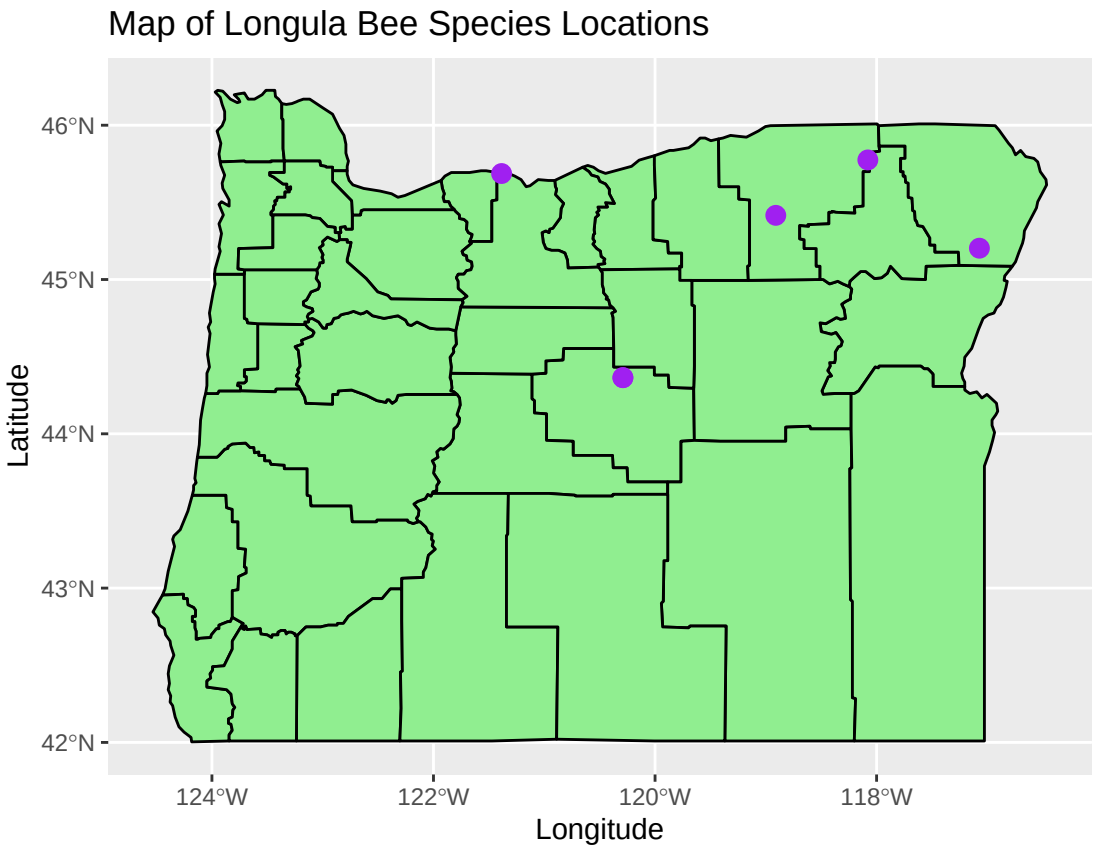
Not so exciting without some kind of background...

Luckily we can download basemaps into R using the map_data function in ggplot (among many others). There is an example for retrieving the Oregon county polygons.

```
or <- map_data("county", "oregon") %>%
  select(lon = long, lat, group, id = subregion)
```

c. Add your species's points to your choice or an Oregon basemap.

```
library(ggspatial)

ggplot() +
  geom_polygon(data = or, aes(x = lon, y = lat, group = group), fill = "lightgreen", color = "black") +
  geom_sf(data = spirit_bee_sf, color = "purple", size=3) +
  ggtitle("Map of Longula Bee Species Locations") +
  labs(x = "Longitude", y = "Latitude")
```



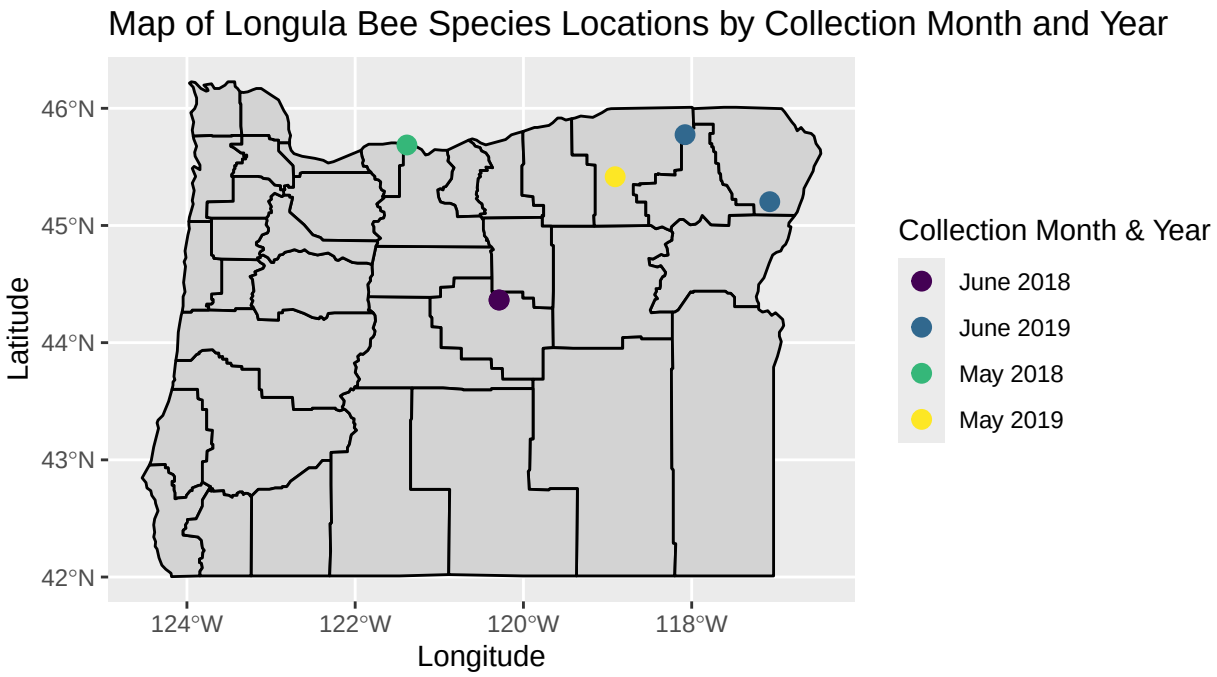
Lab part 3: Cartography

a. Here is your moment to explore your cartographic skills.

1. Add another spatial layer relevant to your final project and tweek the Oregon map in anyway that is useful/visually appealing. You may need to crop that layer to the extent of your species's distribution.
2. Color your points according to some data attribute and add a legend (month collected, county, collector, associated plant, whatever you think is interesting). You may need to circle back to 2.1 to save additional attributes when you converted the dataframe to a spatial object.
3. Fine-tune your map: add a title, make sure the legend label makes sense, add a scale bar (google "add scale bar map ggplot" and choose your favorite package). All maps must always have a scale bar. You can add a N arrow as well, though some cartographers argue that is only necessary if N isn't at the top of the map.
4. Write a figure caption for your map explaining any interesting trends you see.
5. Export you cropped layer to a .shp so you can use it again for your final project.
6. Push this lab to your github repo (just the .Rmd, don't push the data!)

```
# Part 2 (coloring points with legend by month and year)

spirit_bee_sf$Collection.Date <- as.Date(spirit_bee_sf$`Date Collected`, format = "%m/%d/%Y")

spirit_bee_sf$Collection.Month <- format(spirit_bee_sf$Collection.Date, "%B %Y")

ggplot() +
  geom_polygon(data = or, aes(x = lon, y = lat, group = group), fill = "lightgrey", color = "black") +
  geom_sf(data = spirit_bee_sf, aes(color = Collection.Month), size = 3) +
```

```
  scale_color_viridis_d(name = "Collection Month & Year") +
  ggtitle("Map of Longula Bee Species Locations by Collection Month and Year") +
  labs(x = "Longitude", y = "Latitude")
```




```
head(spirit_bee_sf)
```

```
## Simple feature collection with 6 features and 5 fields
## Geometry type: POINT
## Dimension:     XY
## Bounding box:  xmin: -121.3852 ymin: 44.364 xmax: -117.072 ymax: 45.775
## Geodetic CRS:  WGS 84
##   Species          Flower Date Collected                 geometry
## 1 longula Vicia americana       6/2/2018   POINT (-120.29 44.364)
## 2 longula Vicia americana       6/2/2018   POINT (-120.29 44.364)
## 3 longula                      5/17/2018 POINT (-121.3852 45.687)
## 4 longula                      6/19/2019  POINT (-117.072 45.203)
## 5 longula                       5/8/2019   POINT (-118.91 45.416)
## 6 longula                      6/12/2019  POINT (-118.079 45.775)
##   Collection.Date Collection.Month
## 1      2018-06-02        June 2018
## 2      2018-06-02        June 2018
## 3      2018-05-17         May 2018
## 4      2019-06-19        June 2019
## 5      2019-05-08         May 2019
## 6      2019-06-12        June 2019
```

```r
# Adding three 2018 fires to the map (part 1)
rogue_rast = rast("rogue river fire july 2018/hendrix_sbs.tif")
umpqua_rast = rast("umpqua fire july 2018/columbus_sbs.tif")
willamette_rast = rast("willamette national forest fire august 2018/SoilSeverity.tif")

res(rogue_rast) # 30 30
```

```
## [1] 30 30
```

```r
res(umpqua_rast) # 20 20
```

```
## [1] 20 20
```

```r
res(willamette_rast) # 30 30
```

```
## [1] 30 30
```

```r
minmax(rogue_rast) # 1 15
```

```
##     Layer_1
## min       1
## max      15
```

```r
minmax(umpqua_rast) # 1 127
```

```
##     Layer_1
## min       1
## max     127
```

```r
minmax(willamette_rast) # 1 4
```

```
##     SoilBurnSe
## min          1
## max          4
```

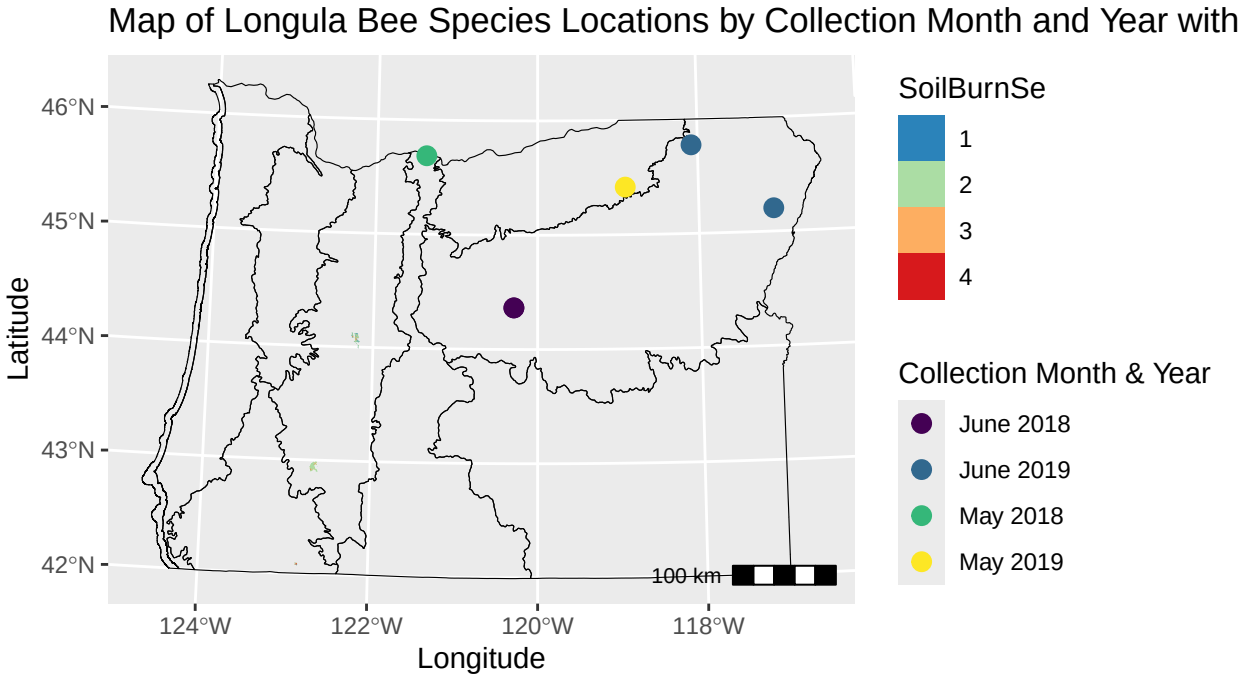
```r
rogue_rast[rogue_rast > 4] <- NA
umpqua_rast[umpqua_rast > 4] <- NA

rogue_rast <- project(rogue_rast, crs(willamette_rast), res=res(willamette_rast))
umpqua_rast <- project(umpqua_rast, crs(willamette_rast), res=res(willamette_rast))

rogue_df <- as.data.frame(rogue_rast, xy = TRUE)
umpqua_df <- as.data.frame(umpqua_rast, xy = TRUE)
willamette_df <- as.data.frame(willamette_rast, xy = TRUE)

willamette_df$SoilBurnSe <- as.character(willamette_df$SoilBurnSe)

willamette_df$SoilBurnSe[willamette_df$SoilBurnSe == "High"] <- "4"
willamette_df$SoilBurnSe[willamette_df$SoilBurnSe == "Moderate"] <- "3"
```

```
willamette_df$SoilBurnSe[willamette_df$SoilBurnSe == "Low"] <- "2"
willamette_df$SoilBurnSe[willamette_df$SoilBurnSe == "Unburned"] <- "1"

willamette_df$SoilBurnSe <- as.factor(willamette_df$SoilBurnSe)

oregon_ecoregions <- st_read("OR-ecoregions/Ecoregions_OregonConservationStrategy.shp")
```

```
## Reading layer ‘Ecoregions_OregonConservationStrategy’ from data source
##   ‘/Users/zoetomlinson/Desktop/college/Bi410 Labs/6_OBA_spatial 2/OR-ecoregions/Ecoregions_OregonCons
##   using driver ‘ESRI Shapefile’
## Simple feature collection with 9 features and 6 fields
## Geometry type: POLYGON
## Dimension:     XY
## Bounding box:  xmin: 183871.7 ymin: 88600.88 xmax: 2345213 ymax: 1675043
## Projected CRS: NAD83 / Oregon GIC Lambert (ft)
```

```
oregon_ecoregions <- st_transform(oregon_ecoregions, crs(willamette_rast))

ggplot() +
  geom_raster(data = willamette_df, aes(x = x, y = y, fill = SoilBurnSe)) +
  geom_raster(data = rogue_df, aes(x = x, y = y, fill = Layer_1)) +
  geom_raster(data = umpqua_df, aes(x = x, y = y, fill = Layer_1)) +
  geom_sf(data = oregon_ecoregions, fill = NA, color = "black") +
  geom_sf(data = spirit_bee_sf, aes(color = Collection.Month), size = 3) +
  scale_fill_brewer(palette = "Spectral", direction = -1) +
  scale_color_viridis_d(name = "Collection Month & Year") +
  labs(
    title = "Map of Longula Bee Species Locations by Collection Month and Year with 3 2018 Fires Plotte
    x = "Longitude",
    y = "Latitude"
  ) +
  annotation_scale(location = "br", width_hint = 0.2)
```

```
## Warning: Raster pixels are placed at uneven horizontal intervals and will be shifted
## i Consider using ‘geom_tile()‘ instead.
## Raster pixels are placed at uneven horizontal intervals and will be shifted
## i Consider using ‘geom_tile()‘ instead.
```




```
ggsave("2018firesBees.png", width = 8, height = 6, dpi = 300)
```

```
## Warning: Raster pixels are placed at uneven horizontal intervals and will be shifted
## i Consider using ‘geom_tile()‘ instead.
## Raster pixels are placed at uneven horizontal intervals and will be shifted
## i Consider using ‘geom_tile()‘ instead.
```

CAPTION: This map displays the distribution of Longula bee species collection points, colored by the month and year of collection. The locations are plotted overlaid with three major 2018 fire events in Oregon, showing the relationship between fire severity and bee distribution.

Analysis of map: so, this isn't the best map because the fires are small and no where near the bee population, so there is likely no correlation between the two. Plus it's really hard to see the fires because of how zoomed out the graph is, but they're there!

We are looking forward to seeing the maps you create!

Lab part 4: Spatial summary statistics

For your final projects, you will likely need to come up with summary statistics that describes the areas around where bees are captured. a. Using the distribution of your chosen bee and the spatial layer you imported in 2.6, extract a meaningful summary statistics from your spatial layer within a buffer of 500, 750 1000 km. b. Create a plot that illustrates this summary data (box plot, barplot, scatter plot, historgram). c. Create a map of your cropped spatial data.

```r
spirit_bee_coords <- spirit_bee_sf %>%
  st_coordinates() %>%
  as.data.frame() %>%
  rename(Longitude = X, Latitude = Y)

spirit_bee_sf <- cbind(spirit_bee_sf, spirit_bee_coords)

buffer_500 <- st_buffer(spirit_bee_sf, dist = 500000)  # 500 km buffer
buffer_750 <- st_buffer(spirit_bee_sf, dist = 750000)  # 750 km buffer
buffer_1000 <- st_buffer(spirit_bee_sf, dist = 1000000) # 1000 km buffer

oregon_ecoregions <- st_transform(oregon_ecoregions, st_crs(spirit_bee_sf))
bee_with_ecoregions <- st_join(spirit_bee_sf, oregon_ecoregions)

buffer_500_ecoregions <- st_intersection(buffer_500, oregon_ecoregions)
```

```
## Warning: attribute variables are assumed to be spatially constant throughout
## all geometries
```

```r
buffer_750_ecoregions <- st_intersection(buffer_750, oregon_ecoregions)
```

```
## Warning: attribute variables are assumed to be spatially constant throughout
## all geometries
```

```r
buffer_1000_ecoregions <- st_intersection(buffer_1000, oregon_ecoregions)
```

```
## Warning: attribute variables are assumed to be spatially constant throughout
## all geometries
```

```r
summary_stats_500 <- buffer_500_ecoregions %>%
  st_drop_geometry() %>%
  filter(!is.na(Ecoregion)) %>%
  group_by(Ecoregion) %>%
  summarise(count = n()) %>%
  left_join(buffer_500_ecoregions %>%
              st_drop_geometry() %>%
              filter(!is.na(Ecoregion)) %>%
              distinct(Ecoregion), by = "Ecoregion")

summary_stats_750 <- buffer_750_ecoregions %>%
  st_drop_geometry() %>%
  filter(!is.na(Ecoregion)) %>%
  group_by(Ecoregion) %>%
  summarise(count = n()) %>%
  left_join(buffer_750_ecoregions %>%
              st_drop_geometry() %>%
              filter(!is.na(Ecoregion)) %>%
              distinct(Ecoregion), by = "Ecoregion")

summary_stats_1000 <- buffer_1000_ecoregions %>%
  st_drop_geometry() %>%
```

```
  filter(!is.na(Ecoregion)) %>%
  group_by(Ecoregion) %>%
  summarise(count = n()) %>%
  left_join(buffer_1000_ecoregions %>%
              st_drop_geometry() %>%
              filter(!is.na(Ecoregion)) %>%
              distinct(Ecoregion), by = "Ecoregion")

summary_stats_500$Buffer <- "500 km"
summary_stats_750$Buffer <- "750 km"
summary_stats_1000$Buffer <- "1000 km"

all_summary_stats <- bind_rows(summary_stats_500, summary_stats_750, summary_stats_1000)

ggplot(all_summary_stats, aes(x = Ecoregion, y = count, fill = Buffer)) +
  geom_bar(stat = "identity", position = "dodge") +
  labs(x = "Ecoregion", y = "Bee Count", title = "Bee Count by Ecoregion and Buffer Size") +
  theme_minimal() +
  theme(axis.text.x = element_text(angle = 45, hjust = 1)) +
  scale_fill_manual(values = c("500 km" = "skyblue", "750 km" = "orange", "1000 km" = "green"))
```