Assignment 3: Data Exploration

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OVERVIEW

This exercise accompanies the lessons in Environmental Data Analytics on Data Exploration.

Directions

1. Rename this file `<FirstLast>_A03_DataExploration.Rmd` (replacing `<FirstLast>` with your first and last name).
2. Change "Student Name" on line 3 (above) with your name.
3. Work through the steps, **creating code and output** that fulfill each instruction.
4. Assign a useful **name to each code chunk** and include ample **comments** with your code.
5. Be sure to **answer the questions** in this assignment document.
6. When you have completed the assignment, **Knit** the text and code into a single PDF file.
7. After Knitting, submit the completed exercise (PDF file) to the dropbox in Canvas.

TIP: If your code extends past the page when knit, tidy your code by manually inserting line breaks.

TIP: If your code fails to knit, check that no `install.packages()` or `View()` commands exist in your code.

Set up your R session

1. Load necessary packages (tidyverse, lubridate, here), check your current working directory and upload two datasets: the ECOTOX neonicotinoid dataset (ECOTOX_Neonicotinoids_Insects_raw.csv) and the Niwot Ridge NEON dataset for litter and woody debris (NEON_NIWO_Litter_massdata_2018-08_raw.csv). Name these datasets "Neonics" and "Litter", respectively. Be sure to include the subcommand to read strings in as factors.

```r
library(tidyverse)
#load package
library(lubridate)
#load package
library(here)
#load package
Neonics = read.csv("./Data/Raw/ECOTOX_Neonicotinoids_Insects_raw.csv")
#upload file
Litter = read.csv("./Data/Raw/NEON_NIWO_Litter_massdata_2018-08_raw.csv")
#upload file
```

Learn about your system

2. The neonicotinoid dataset was collected from the Environmental Protection Agency's ECOTOX Knowledgebase, a database for ecotoxicology research. Neonicotinoids are a class of insecticides used widely in agriculture. The dataset that has been pulled includes all studies published on insects. Why might we be interested in the ecotoxicology of neonicotinoids on insects? Feel free to do a brief internet search if you feel you need more background information.

   Answer: we should study the ecotoxicology of neonicotinoids on insects because most pollinators are insects, which are essential for the reproduction of many plants, including crops that humans rely on for food. The long-lasting presence of neonicotinoids means they can harm pollinators even if applied months before blooming (Understanding Neonicotinoids, n.d.).

3. The Niwot Ridge litter and woody debris dataset was collected from the National Ecological Observatory Network, which collectively includes 81 aquatic and terrestrial sites across 20 ecoclimatic domains. 32 of these sites sample forest litter and woody debris, and we will focus on the Niwot Ridge long-term ecological research (LTER) station in Colorado. Why might we be interested in studying litter and woody debris that falls to the ground in forests? Feel free to do a brief internet search if you feel you need more background information.

   Answer: litter and woody debris are crucial to forest and stream ecosystems as it influences carbon budgets and nutrient cycling, serves as an energy source for aquatic systems, provides habitat for both terrestrial and aquatic species, and adds structure that affects water flow and sediment movement (Scheungrab et al., 2000).

4. How is litter and woody debris sampled as part of the NEON network? Read the NEON_Litterfall_UserGuide.pdf document to learn more. List three pieces of salient information about the sampling methods here:

   Answer: litter and woody debris are sampled in the NEON network by collecting dry weights from litter traps according to specific plant functional types. The data collected from these sampling events are initially considered raw data (Level 0) and are then processed and quality checked to create a quality-controlled product (Level 1). This process involves automated quality assurance and control procedures, and detailed metadata is provided alongside the data for publication through the NEON data portal (Jones & Flagg, n.d.). 1.”In sites with >50% aerial cover of woody vegetation >2m in height, placement of litter traps is random, using a randomized list of grid cell locations. In sites with <50% woody vegetation cover or patchy vegetation, trap placement is targeted under qualifying vegetation (Jones & Flagg, n.d.).” 2.” Ground traps are sampled once per year, while elevated traps are sampled frequently (1x every 2 weeks) in deciduous forest sites during senescence, and infrequently (1x every 1-2 months) at evergreen sites (Jones & Flagg, n.d.).” 3.”Woody vegetation cover, as measured by NEON’s Airborne Observation Platform and/or vegetation structure protocols, may be used to scale up litterfall production from point measurements (Jones & Flagg, n.d.).”

Obtain basic summaries of your data (Neonics)

5. What are the dimensions of the dataset?

```r
view(as.data.frame(Neonics))
view(as.data.frame(Litter))
#turn two data sets into data frames that is clearer to check
```

6. Using the `summary` function on the "Effect" column, determine the most common effects that are studied. Why might these effects specifically be of interest? [Tip: The `sort()` command is useful for listing the values in order of magnitude…]

```
common_effects = table(Neonics$Effect)
#make a table for occurrence number of each type of effect
sort(common_effects, decreasing = TRUE)
```

```
##
##       Population        Mortality         Behavior Feeding behavior
##             1803             1493              360              255
##     Reproduction      Development        Avoidance         Genetics
##              197              136              102               82
##        Enzyme(s)           Growth       Morphology    Immunological
##               62               38               22               16
##     Accumulation     Intoxication     Biochemistry          Cell(s)
##               12               12               11                9
##       Physiology        Histology        Hormone(s)
##                7                5                1
```

```
#rearrange the table in descending order
```

Answer: the most common effec is population. Studying the effects of neonicotinoids on population, mortality, reproduction, feeding behavior, and development is vital because these factors influence insect survival and biodiversity, which are essential for pollination and food security. Understanding these impacts helps identify potential disruptions in ecosystems that affect species interactions and ecosystem functions.

7. Using the `summary` function, determine the six most commonly studied species in the dataset (common name). What do these species have in common, and why might they be of interest over other insects? Feel free to do a brief internet search for more information if needed.[TIP: Explore the help on the `summary()` function, in particular the `maxsum` argument…]

```
species = table(Neonics$Species.Common.Name)
#make a table for the occurrence number of each species's common name
sort(species, decreasing = TRUE)
```

```
##
##                             Honey Bee                        Parasitic Wasp
##                                   667                                   285
##                  Buff Tailed Bumblebee                  Carniolan Honey Bee
##                                   183                                   152
##                            Bumble Bee                     Italian Honeybee
##                                   140                                   113
##                       Japanese Beetle                    Asian Lady Beetle
##                                    94                                    76
##                        Euonymus Scale                             Wireworm
##                                    75                                    69
##                     European Dark Bee                    Minute Pirate Bug
##                                    66                                    62
##                   Asian Citrus Psyllid                        Parastic Wasp
##                                  60                                 58
##              Colorado Potato Beetle                    Parasitoid Wasp
##                                  57                                 51
##                 Erythrina Gall Wasp                       Beetle Order
##                                  49                                 47
##         Snout Beetle Family, Weevil           Sevenspotted Lady Beetle
##                                  47                                 46
##                      True Bug Order              Buff-tailed Bumblebee
##                                  45                                 39
##                        Aphid Family                     Cabbage Looper
##                                  38                                 38
##                Sweetpotato Whitefly                      Braconid Wasp
##                                  37                                 33
##                        Cotton Aphid                     Predatory Mite
##                                  33                                 33
##              Ladybird Beetle Family                         Parasitoid
##                                  30                                 30
##                       Scarab Beetle                      Spring Tiphia
##                                  29                                 29
##                         Thrip Order               Ground Beetle Family
##                                  29                                 27
##                  Rove Beetle Family                      Tobacco Aphid
##                                  27                                 27
##                        Chalcid Wasp             Convergent Lady Beetle
##                                  25                                 25
##                       Stingless Bee                  Spider/Mite Class
##                                  25                                 24
##                 Tobacco Flea Beetle                   Citrus Leafminer
##                                  24                                 23
##                     Ladybird Beetle                          Mason Bee
##                                  23                                 22
##                            Mosquito                      Argentine Ant
##                                  22                                 21
##                              Beetle         Flatheaded Appletree Borer
##                                  21                                 20
##                Horned Oak Gall Wasp                 Leaf Beetle Family
##                                  20                                 20
##                   Potato Leafhopper         Tooth-necked Fungus Beetle
##                                  20                                 20
##                        Codling Moth          Black-spotted Lady Beetle
##                                  19                                 18
##                        Calico Scale                Fairyfly Parasitoid
##                                  18                                 18
##                         Lady Beetle             Minute Parasitic Wasps
##                                  18                                 18
##                           Mirid Bug                   Mulberry Pyralid
##                                  18                                 18
##                            Silkworm                     Vedalia Beetle
##                                  18                                 18
##               Araneoid Spider Order                          Bee Order
##                                  17                                 17
##                      Egg Parasitoid                       Insect Class
##                                  17                                 17
##            Moth And Butterfly Order       Oystershell Scale Parasitoid
##                                 17                                 17
## Hemlock Woolly Adelgid Lady Beetle              Hemlock Wooly Adelgid
##                                 16                                 16
##                               Mite                        Onion Thrip
##                                 16                                 16
##              Western Flower Thrips                       Corn Earworm
##                                 15                                 14
##                  Green Peach Aphid                          House Fly
##                                 14                                 14
##                          Ox Beetle                 Red Scale Parasite
##                                 14                                 14
##                 Spined Soldier Bug              Armoured Scale Family
##                                 14                                 13
##                   Diamondback Moth                      Eulophid Wasp
##                                 13                                 13
##                  Monarch Butterfly                      Predatory Bug
##                                 13                                 13
##              Yellow Fever Mosquito                Braconid Parasitoid
##                                 13                                 12
##                       Common Thrip       Eastern Subterranean Termite
##                                 12                                 12
##                             Jassid                         Mite Order
##                                 12                                 12
##                          Pea Aphid                   Pond Wolf Spider
##                                 12                                 12
##           Spotless Ladybird Beetle             Glasshouse Potato Wasp
##                                 11                                 10
##                           Lacewing            Southern House Mosquito
##                                 10                                 10
##            Two Spotted Lady Beetle                         Ant Family
##                                 10                                  9
##                       Apple Maggot                  Asiatic Honey Bee
##                                  9                                  9
##                Eulophid Parasitoid                    Lacewing Family
##                                  9                                  9
##                 Mealybug Destroyer             Alfalfa Leafcutter Bee
##                                  9                                  8
##                                Bee                          Bumblebee
##                                  8                                  8
##             Chilean Predatory Mite                    Dwarf Honey Bee
##                                  8                                  8
##          Neotropical Stingless Bee              Parasitic Wasp Family
##                                  8                                  8
##                Spiralling Whitefly                 Beetle Mite Family
##                                  8                                  7
##                          Chinch Bug               Macedonian Honey Bee
##                                  7                                  7
##                               Moth                   Potato Tuberworm
##                                  7                                  7
##                Russian Wheat Aphid                     Soldier Beetle
##                                  7                                  7
##         Southern One-Year Canegrub                Tarnished Plant Bug
##                                  7                                  7
##                    Ambrosia Beetle                         Aphid Wasp
##                                  6                                  6
##                  Black Vine Weevil                  Childers Canegrub
##                                  6                                  6
##                Coconut Leaf Beetle      Elevenspotted Ladybird Beetle
##                                  6                                  6
##                      Encyrtid Wasp                  European Red Mite
##                                  6                                  6
##                      Fall Armyworm                          Fruit Fly
##                                  6                                  6
##                          Hover Fly         Oblique Banded Leaf Roller
##                                  6                                  6
##                   Obscure Mealybug             Oribatid Mite Suborder
##                                  6                                  6
##                  Pistachio Psyllid             Redbay Ambrosia Beetle
##                                  6                                  6
##                Silverleaf Whitefly                      Soybean Aphid
##                                  6                                  6
##               Subterranean Termite                              Thrip
##                                  6                                  6
##            Two-Spotted Spider Mite                        Apple Aphid
##                                  6                                  5
##                  Brown Planthopper                             Earwig
##                                  5                                  5
##                  Green June Beetle                      Hornfaced Bee
##                                  5                                  5
##          Long Horned Beetle Family                      Plum Curculio
##                                  5                                  5
##                        Rove Beetle                     San Jose Scale
##                                  5                                  5
##                     Scelionid Wasp              Speckled Cutworm Moth
##                                  5                                  5
##                       Thrip Family                                Ant
##                                  5                                  4
##             Cabbage Seedpod Weevil              Common Green Lacewing
##                                  4                                  4
##               Eucalyptus Gall Wasp              European Apple Sawfly
##                                  4                                  4
##                 European Honey Bee       European Tarnished Plant Bug
##                                  4                                  4
##                   Garden Symphylan                   Linyphiid Spider
##                                  4                                  4
##                       Onion Maggot                    Oriental Beetle
##                                  4                                  4
##                  Parsnip Seed Wasp                Pea And Bean Weevil
##                                  4                                  4
##                        Pear Sucker              Red Imported Fire Ant
##                                  4                                  4
##            Striped Cucumber Beetle                   Sugarcane Beetle
##                                  4                                  4
##                               Wasp                 Wolf Spider Family
##                                  4                                  4
##             Yellow-faced Bumblebee               Ambrosia Bark Beetle
##                                  4                                  3
##              Asian Ambrosia Beetle                      Beetle Family
##                                  3                                  3
##                    Birch Leafminer                   Black Twig Borer
##                                  3                                  3
##           Braconid Parasitoid Wasp               California Red Scale
##                                  3                                  3
##               Crucifer Flea Beetle                            Cutworm
##                                  3                                  3
##              Delphacid Planthopper           Egyptian Cotton Leafworm
##                                  3                                  3
##                Encyrtid Parasitoid           Fly/Mosquito/Midge Order
##                                  3                                  3
##      Formosan Subterranean Termite           Fruit-tree Pinhole Borer
##                                  3                                  3
##              Green Rice Leafhopper                      Ground Beetle
##                                  3                                  3
##                   Ichneumonid Wasp       Large-Jawed Orb Weaver Family
##                                  3                                  3
##                   Leaf Cutting Ant            Mediterranean Fruit Fly
##                                  3                                  3
##                   Minute Flour Bug                        Mite Family
##                                  3                                  3
##                        Moth Family                 Negatoria Canegrub
##                                  3                                  3
##                  Sap Beetle Family                 Scale Insect Order
##                                  3                                  3
##               Scarab Beetle Family            Sheet-Web Weaver Family
##                                  3                                  3
##                             Spider                     Sugarcane Grub
##                                  3                                  3
##                 Tenebrionid Beetle                  Alfalfa Plant Bug
##                                  3                                  2
##                         Alkali Bee                              Aphid
##                                  2                                  2
##                       Assassin Bug                    Azalea Lace Bug
##                                  2                                  2
##                       Banana Aphid                        Brown Scale
##                                  2                                  2
##                     Brown Stinkbug                            Budworm
##                                  2                                  2
##                      Cabbage Aphid                      Cabbage White
##                                  2                                  2
##                     Cardamom Thrip                      Carrot Weevil
##                                  2                                  2
##                  Celer Crab Spider                    Centipede Class
##                                  2                                  2
##                    Citricola Scale                  Clouded Plant Bug
##                                  2                                  2
##                 Coffee Bean Weevil                  Cotton Fleahopper
##                                  2                                  2
##            Egyptian Alfalfa Weevil                    Engraver Beetle
##                                  2                                  2
##               Fig Longicorn Beetle         Glassy-winged Sharpshooter
##                                  2                                  2
##                  Hawthorn Lace Bug               Hister Beetle Family
##                                  2                                  2 
##              Jumping Spider Family                 Lined Click Beetle 
##                                  2                                  2 
##                  Maple Spider Mite                  Meshweaver Spider 
##                                  2                                  2 
##           Minute Pirate Bug Family                     Predaceous Fly 
##                                  2                                  2 
##               Pygmy Mangold Beetle                        Rose Sawfly 
##                                  2                                  2 
##               Serpentine Leafminer              Spider Mite Destroyer 
##                                  2                                  2 
##        Spotted Tentiform Leafminer                          Stink Bug 
##                                  2                                  2 
##                 Tawny Mole Cricket            Tick/Chigger/Mite Order 
##                                  2                                  2 
##                Turf Running-spider                       Turnip Aphid 
##                                  2                                  2 
##                Western Bigeyed Bug                 Western Damsel Bug 
##                                  2                                  2 
##                  Western Plant Bug       White Apple Leafhopper Nymph 
##                                  2                                  2 
##           White-backed Planthopper             Whitemarked Fleahopper 
##                                  2                                  2 
##              Antlike Flower Beetle   Banded Soft-winged Flower Beetle 
##                                  1                                  1 
##              Banded Sunflower Moth                         Bee Family 
##                                  1                                  1 
##                      Beet Armyworm                 Black Citrus Aphid 
##                                  1                                  1 
##                 Blue Alfalfa Aphid                   Cabbage Root Fly 
##                                  1                                  1 
##                 Cactus Lady Beetle                    Citrus Red Mite 
##                                  1                                  1 
##               Cottony Cushion Sale                  Crapemyrtle Aphid 
##                                  1                                  1 
##                   Damselbug Family                Ectoparasitoid Wasp 
##                                  1                                  1 
##                English Grain Aphid                           Fairyfly 
##                                  1                                  1 
##                        Flea Beetle                         Gall Midge 
##                                  1                                  1 
##   Grasshopper/Cricket/Locust Order                Greenhouse Whitefly 
##                                  1                                  1 
##         Grey Sunflower Seed Weevil            Harvestman Spider Order 
##                                  1                                  1 
##                Hawthorn Leaf Miner      Longtailed Fruit Fly Parasite 
##                                  1                                  1 
##                Minute Lady Beetles                Painted Maple Aphid 
##                                  1                                  1 
##                      Pepper Weevil                  Pine False Webworm 
##                                  1                                  1 
##                          Plant Bug                      Pollen Beetle 
##                                  1                                  1 
##                    Predacious Mite                       Predator Bug 
##                                  1                                  1
##              Pseudocentipede Class             Pteromalid Wasp Family
##                                  1                                  1
##          Red Sunflower Seed Weevil              Rice Leaf Folder Moth
##                                  1                                  1
##                   Rose Grain Aphid                Scale Picnic Beetle
##                                  1                                  1
##                Shiny Spider Beetle                 Southern Army Worm
##                                  1                                  1
##                       Spirea Aphid      Spotted Sunflower Stem Weevil
##                                  1                                  1
##          Strawberry Blossom Weevil                    Sunflower Midge
##                                  1                                  1
##                     Sunflower Moth           Ten-spot Ladybird Beetle
##                                  1                                  1
##                      Tobacco Thrip           Twicestabbed Lady Beetle
##                                  1                                  1
##                        Wasp Family                             Weevil
##                                  1                                  1
##             Yellow Mealworm Beetle
##                                  1
```

```
#rearrange the table in descending order
```

> Answer: the six most commonly studied species are Honey Bee, Parasitic Wasp, Buff Tailed Bumble Bee, Carniolan Honey Bee, Bumble Bee, and Italian Honeybee. People are more interested in bees because they can all directly impact the reproduction of flowering plants and the overall health of ecosystems. Their activities support biodiversity and help maintain the balance of various habitats.

8. Concentrations are always a numeric value. What is the class of `Conc.1..Author.` column in the dataset, and why is it not numeric? [Tip: Viewing the dataframe may be helpful…]

```
class(Neonics$Conc.1..Author.)
```

```
## [1] "character"
```

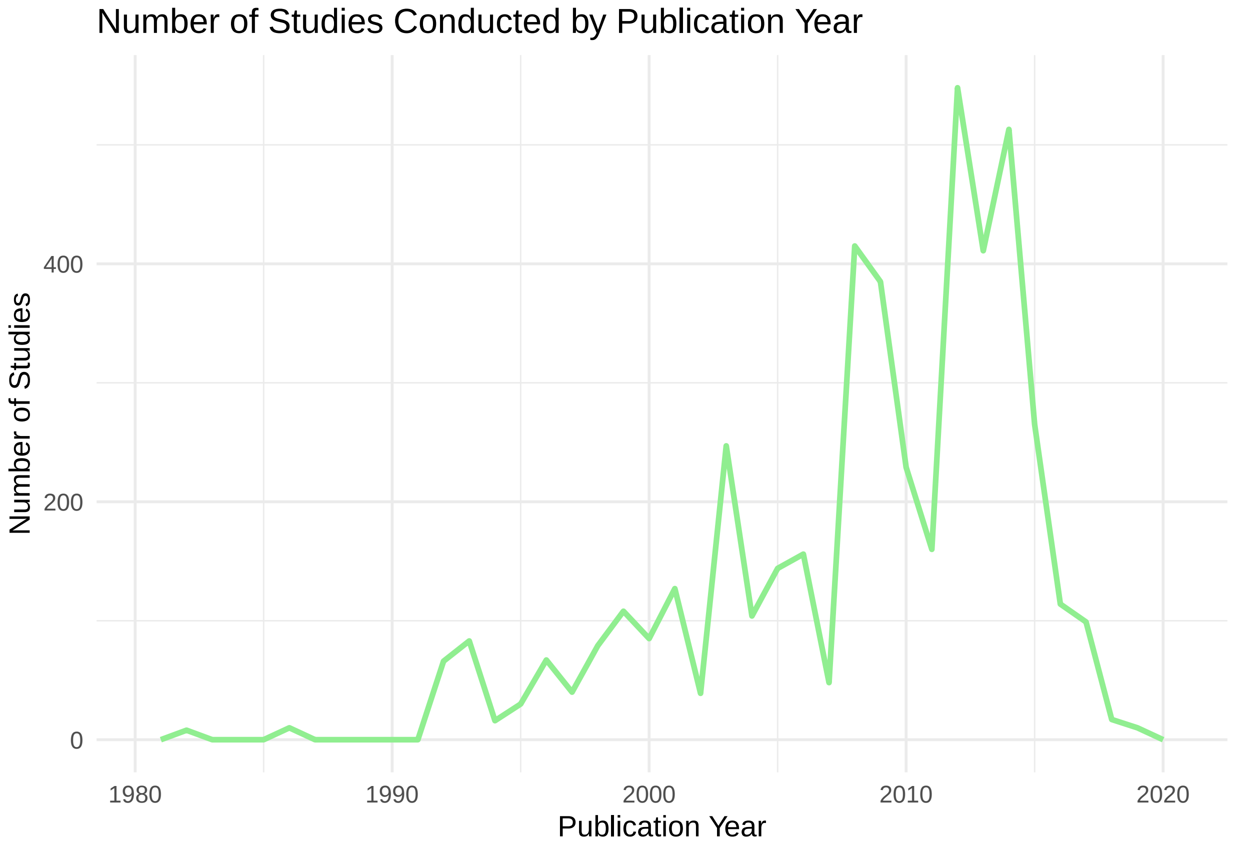
```
#check the class of `Conc.1..Author.`
```

> Answer: the class of 'Conc.1..Author.' is character. It is not numeric value because it contains some letters and symbols like "/" and "NR".

Explore your data graphically (Neonics)

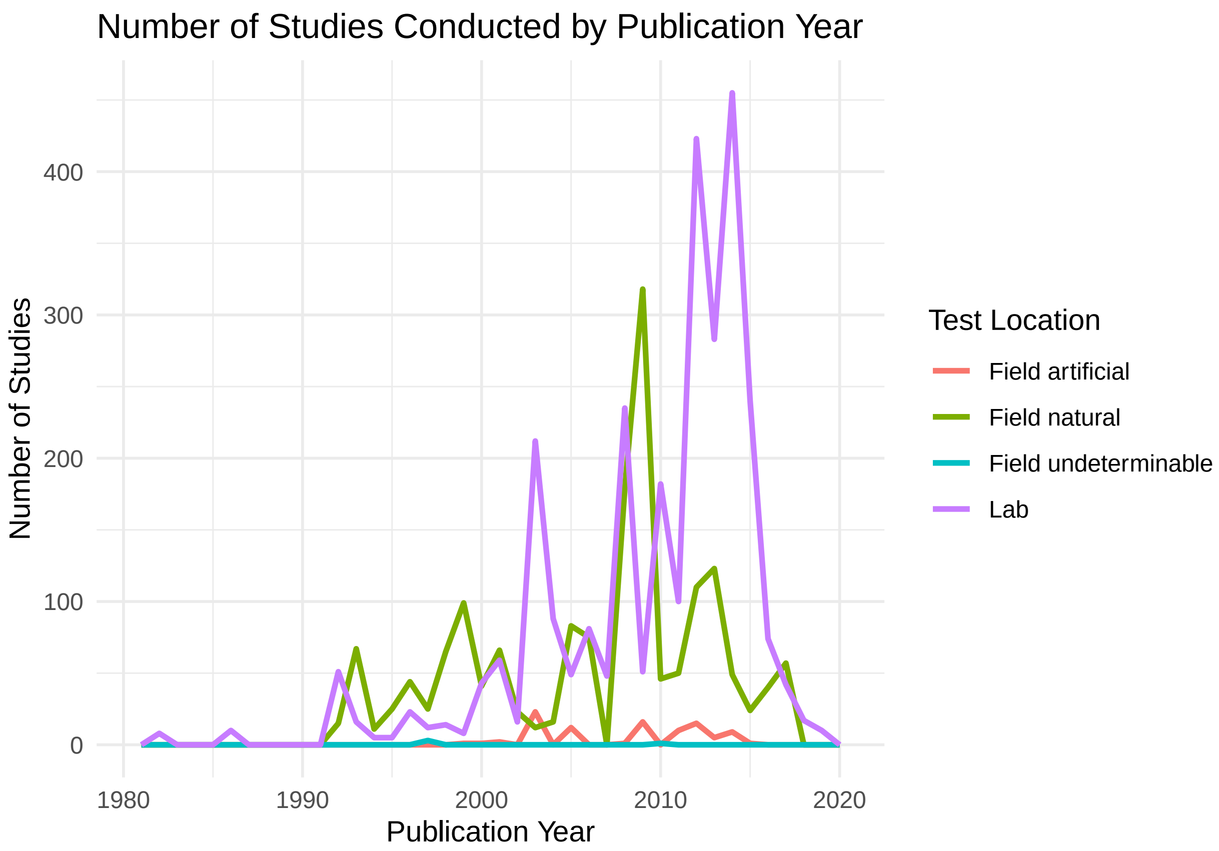
9. Using `geom_freqpoly`, generate a plot of the number of studies conducted by publication year.

```
library(ggplot2)
#load the package
ggplot(data = Neonics, aes(x = Publication.Year)) + #select the data
  geom_freqpoly(binwidth = 1, color = "palegreen2", linewidth = 1) + #determine details
  labs(title = "Number of Studies Conducted by Publication Year",
       x = "Publication Year",
       y = "Number of Studies") + #name the plot
  theme_minimal() #choose plot theme
```



10. Reproduce the same graph but now add a color aesthetic so that different Test.Location are displayed as different colors.

```
ggplot(data = Neonics, aes(x = Publication.Year, color = Test.Location)) + #select data
  geom_freqpoly(binwidth = 1, linewidth = 1) + #determine details
  labs(title = "Number of Studies Conducted by Publication Year",
       x = "Publication Year",
       y = "Number of Studies") + #name the plot
  theme_minimal() + #choose plot theme
  scale_color_discrete(name = "Test Location") #name the legend
```



Interpret this graph. What are the most common test locations, and do they differ over time?

> Answer: in general, the lab is the most common test location. Before the year 2000, studies conducted in the field were more numerous than those done in the lab. Around 2014, studies conducted in the lab reached their peak. “Field undeterminable” is the least used test location, appearing almost as a line overlapping with the x-axis.

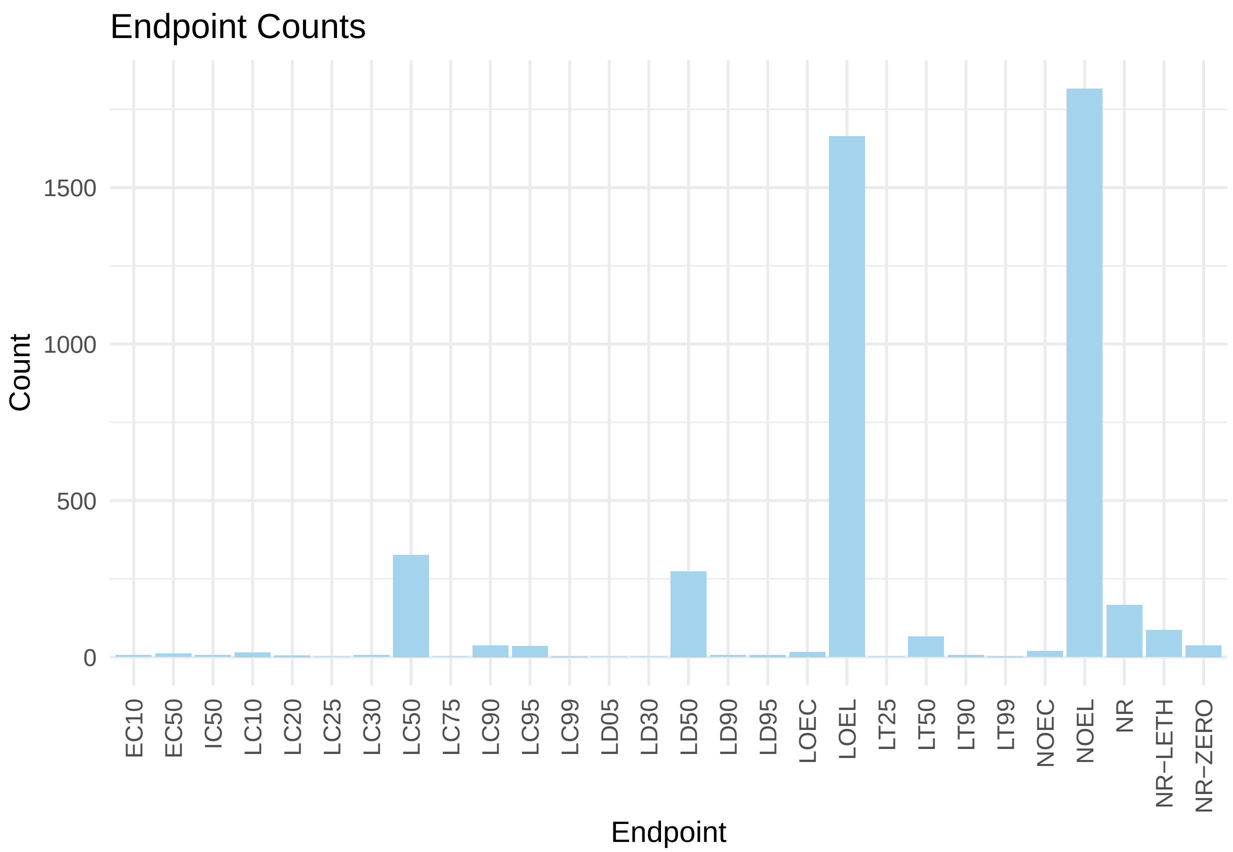
11. Create a bar graph of Endpoint counts. What are the two most common end points, and how are they defined? Consult the ECOTOX_CodeAppendix for more information.

[**TIP**: Add `theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust=1))` to the end of your plot command to rotate and align the X-axis labels…]

```
library(dplyr)
endpoint = Neonics %>% count(Endpoint)
#count the Endpoint
endpoint
```

```
##    Endpoint   n
## 1      EC10   6
## 2      EC50  11
## 3      IC50   6
## 4      LC10  15
## 5      LC20   5
## 6      LC25   1
## 7      LC30    6
## 8      LC50  327
## 9      LC75    1
## 10     LC90   37
## 11     LC95   36
## 12     LC99    2
## 13     LD05    1
## 14     LD30    1
## 15     LD50  274
## 16     LD90    6
## 17     LD95    7
## 18     LOEC   17
## 19     LOEL 1664
## 20     LT25    1
## 21     LT50   65
## 22     LT90    7
## 23     LT99    2
## 24     NOEC   19
## 25     NOEL 1816
## 26       NR  167
## 27  NR-LETH   86
## 28  NR-ZERO   37
```

```
ggplot(data = endpoint, aes(x = Endpoint, y = n)) + #select data
  geom_bar(stat = "identity", fill = "lightskyblue2") + #determine details
  labs(title = "Endpoint Counts",
       x = "Endpoint",
       y = "Count") + #name the plot
  theme_minimal() + #choose plot theme
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust = 1))
```



```
  #rotate and align the X-axis labels
```

Answer: the two most common endpoint are LOEL and NOEL. "Lowest-observable-effect-level: lowest dose (concentration) producing effects that were significantly different (as reported by authors) from responses of controls (LOEAL/LOEC). No-observable-effect-level: highest dose (concentration) producing effects not significantly different from responses of controls according to author's reported statistical test (NOEAL/NOEC) (ECOTOX_CodeAppendix).

Explore your data (Litter)

12. Determine the class of collectDate. Is it a date? If not, change to a date and confirm the new class of the variable. Using the `unique` function, determine which dates litter was sampled in August 2018.

```
class(Litter$collectDate)
```

```
## [1] "character"
```

```
#check the class of collectDate
collect_date = as.Date(Litter$collectDate, format = "%Y-%m-%d")
#change the class to date
class(collect_date)
```

```
## [1] "Date"
```

```
#check the class again
August_2018 = unique(collect_date[format(collect_date, "%Y-%m") == "2018-08"])
#determine which dates litter was sampled in August 2018
August_2018
```

```
## [1] "2018-08-02" "2018-08-30"
```

13. Using the **unique** function, determine how many different plots were sampled at Niwot Ridge. How is the information obtained from **unique** different from that obtained from **summary**?

```
unique(Litter$siteID)
```

```
## [1] "NIWO"
```

```
#determine how many different plots were sampled at Niwot Ridge
summary(Litter$siteID)
```

```
##    Length     Class      Mode 
##       188 character character
```

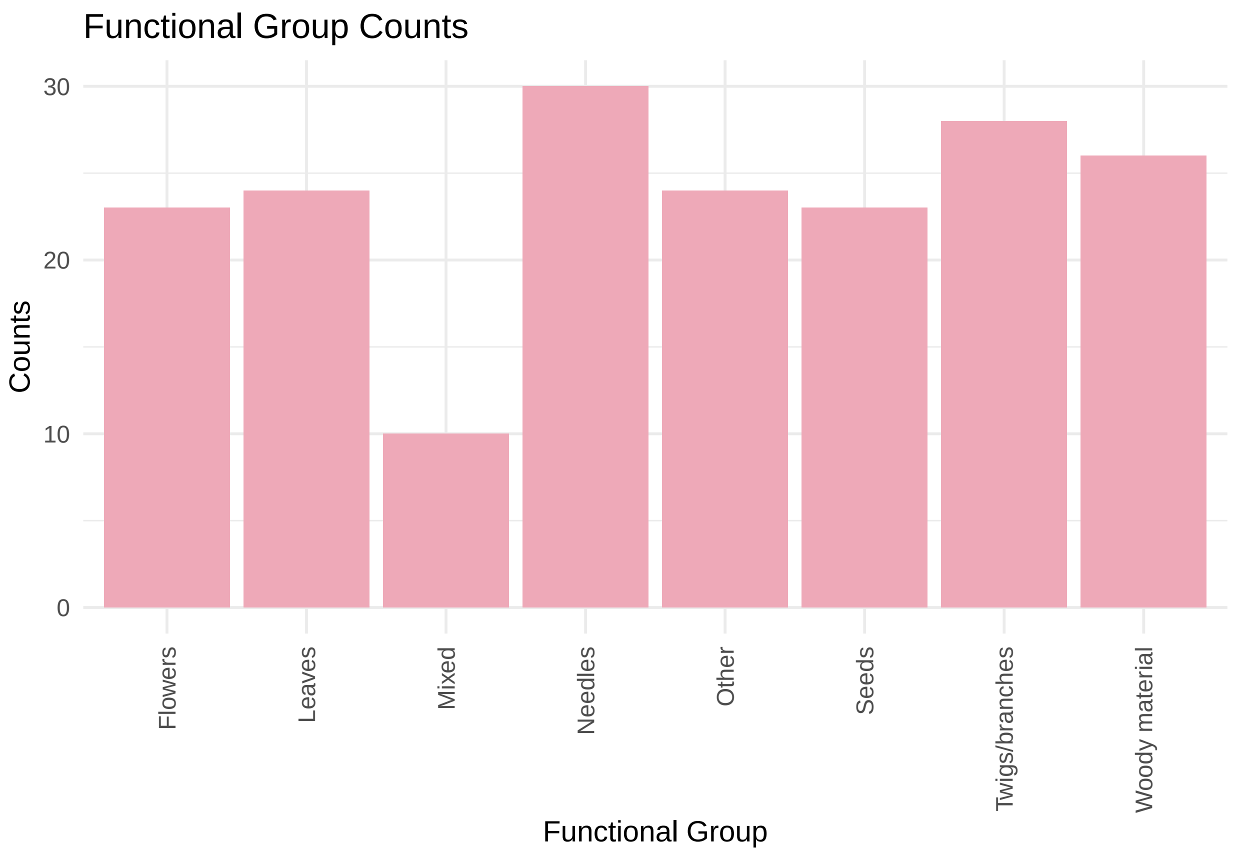
Answer: the result from 'unique' function is "NIWO", which means all the plots were sampled at Niwot Ridge. We know there are 188 plots, so 188 different plots were sampled at NIWO. The result from 'summary' function shows the length, class, and mode.

14. Create a bar graph of functionalGroup counts. This shows you what type of litter is collected at the Niwot Ridge sites. Notice that litter types are fairly equally distributed across the Niwot Ridge sites.

```
functional_group = Litter %>% count(functionalGroup)
#count the functionalGroup
functional_group
```

```
##   functionalGroup  n
## 1         Flowers 23
## 2          Leaves 24
## 3           Mixed 10
## 4         Needles 30
## 5           Other 24
## 6           Seeds 23
## 7  Twigs/branches 28
## 8  Woody material 26
```

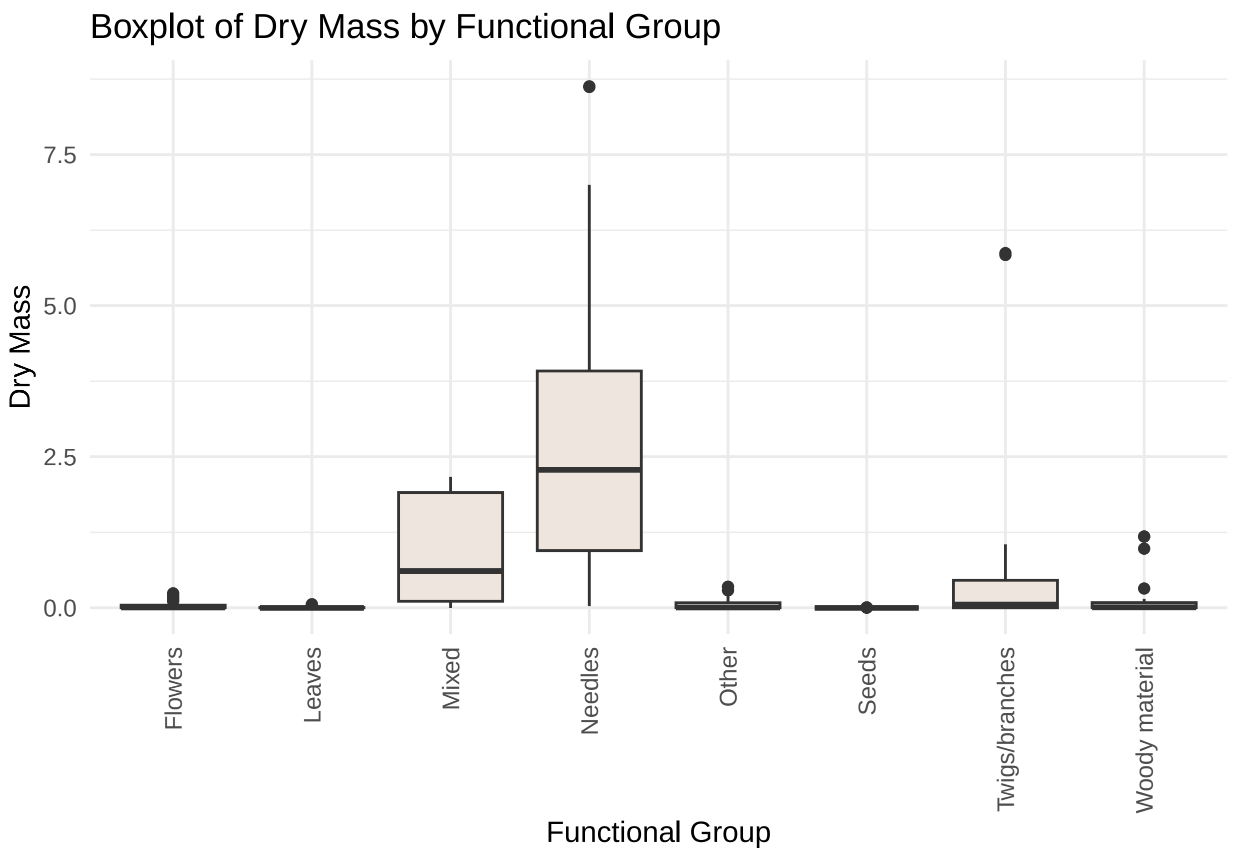
```
ggplot(data = functional_group, aes(x = functionalGroup, y = n)) + #select data
  geom_bar(stat = "identity", fill = "pink2") + #determine details
  labs(title = "Functional Group Counts",
       x = "Functional Group", y = "Counts") + #name the plot
  theme_minimal() + #choose plot theme
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust = 1))
```



```
  #rotate and align the X-axis labels
```

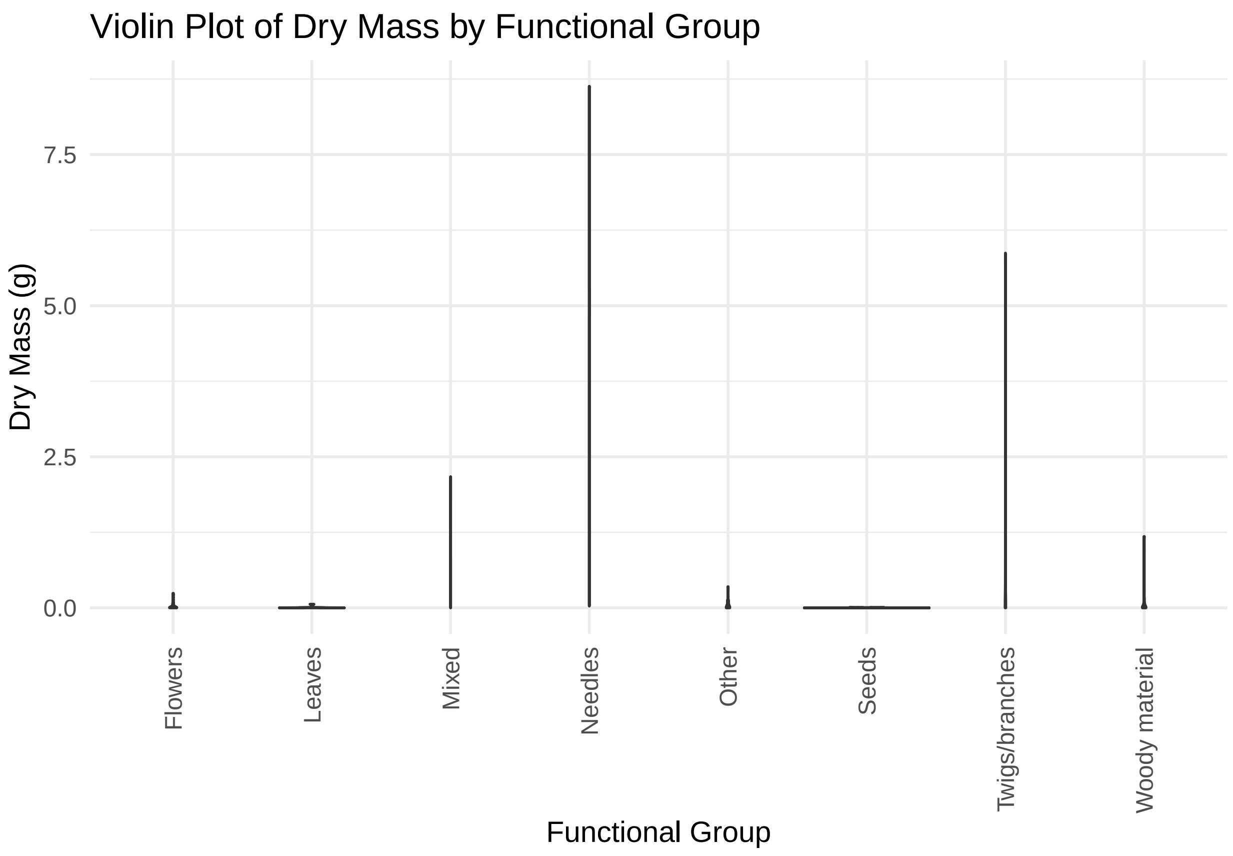
15. Using `geom_boxplot` and `geom_violin`, create a boxplot and a violin plot of dryMass by functionalGroup.

```
ggplot(data = Litter, aes(x = functionalGroup, y = dryMass)) + #select data
  geom_boxplot(fill = "seashell2") + #determine detail
  labs(title = "Boxplot of Dry Mass by Functional Group",
       x = "Functional Group", y = "Dry Mass") + #name the plot
  theme_minimal() + #choose plot theme
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust = 1))
```



```
  #rotate and align the X-axis labels

ggplot(data = Litter, aes(x = functionalGroup, y = dryMass)) + #select data
  geom_violin(fill = "indianred2") + #determine detail
  labs(title = "Violin Plot of Dry Mass by Functional Group",
       x = "Functional Group", y = "Dry Mass (g)") + #name the plot
  theme_minimal() + #choose plot theme
  theme(axis.text.x = element_text(angle = 90, vjust = 0.5, hjust = 1))
```



```
#rotate and align the X-axis labels
```

Why is the boxplot a more effective visualization option than the violin plot in this case?

> Answer: in this case, many values are close to zero which means the variation of the data points is small, resulting in vertical lines and not look like the violin at all.

What type(s) of litter tend to have the highest biomass at these sites?

> Answer: needles tend to have the highest biomass at these sites.