# 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 Sakai.

**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. Check your working directory, load necessary packages (tidyverse, lubridate), 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.

```
getwd()
```

```
## [1] "/home/guest/EDE_Fall2023"
```

```
#install.packages("tidyverse")
#install.packages("lubridate")
library(tidyverse)
library(lubridate)

Neonics <- read.csv("./Data/Raw/ECOTOX_Neonicotinoids_Insects_raw.csv",stringsAsFactors = TRUE)

Litter <- read.csv("./Data/Raw/NEON_NIWO_Litter_massdata_2018-08_raw.csv",stringsAsFactors = TRUE)
```

## 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: Neonictonoids are a class of pesticidies that kill insects by inhibiting their nervous system fuction. Their initial use was to target insects and pests that impact crop production and quality, but the mechanism they target is found widely across insects making it a non target pesticide. From an ecotoxicity perpsective, folks are interested in learning about the wide ranging impact of this pesticide and its effect on pollinator species such as bees.

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 play an essential role in nutrient cycling in the environment alongside carbon budgeting. Critters and organisms make their home in the debris and fallen litter, which been linked to mantaining soil balance, health and quality.

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: 1. Woody Debris is collected from Elevated and Ground level using square or rectengular traps 2. Sampling only occurs at tower plots which are chosen randomly. Trap placements within the plots is randomized or targeted depending on vegetation. 3. Ground traps are sampled one per year, target sampling changes depending on the data needed. Once everything is sampled and mass is processed, it is reported at the spatial resolution of a single trap and the temporal resolution of a single collection event.

## Obtain basic summaries of your data (Neonics)

5. What are the dimensions of the dataset?

```r
dim(Neonics)
```

```
## [1] 4623   30
```

```r
# 4623 rows and 30 columns
```

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?

```r
summary(Neonics$Effect)
```

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

> Answer: Based on the summary Mortality, Population, Behavior, Feeding Behavior, Development and Reproduction are commonly studied endpoints. This makes sense because if a pesticide causes death, mortality and population can be used to track the status of an insect species in the environment. If a pesticide does not cause, it could impact other functions such as reproduction or development which has larger species impact. Lastly, studying Behavior and feeding behavior gives insight into the insects' role in the environment, helping us predict what ecosystems may collapse without their presence.

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: The `sort()` command can sort the output of the summary command…]

```r
summary(Neonics)
```

```
##    CAS.Number       
##  Min.   : 58842209  
##  1st Qu.:138261413  
##  Median :138261413  
##  Mean   :147651982  
##  3rd Qu.:153719234  
##  Max.   :210880925  
##                     
##                                                                                  Chemical.Name
##  (2E)-1-[(6-Chloro-3-pyridinyl)methyl]-N-nitro-2-imidazolidinimine                     :2658  
##  3-[(2-Chloro-5-thiazolyl)methyl]tetrahydro-5-methyl-N-nitro-4H-1,3,5-oxadiazin-4-imine: 686  
##  [C(E)]-N-[(2-Chloro-5-thiazolyl)methyl]-N'-methyl-N''-nitroguanidine                  : 452  
##  (1E)-N-[(6-Chloro-3-pyridinyl)methyl]-N'-cyano-N-methylethanimidamide                 : 420  
##  N''-Methyl-N-nitro-N'-[(tetrahydro-3-furanyl)methyl]guanidine                         : 218  
##  [N(Z)]-N-[3-[(6-Chloro-3-pyridinyl)methyl]-2-thiazolidinylidene]cyanamide             : 128  
##  (Other)                                                                               :  61  
##                                                         Chemical.Grade
##  Not reported                                                  :3989  
##  Technical grade, technical product, technical formulation: 422  
##  Pestanal grade                                                :  93  
##  Not coded                                                     :  53  
##  Commercial grade                                              :  27  
##  Analytical grade                                              :  15  
##  (Other)                                                       :  24
```

```
##                                                  Chemical.Analysis.Method
## Measured                                                    : 230
## Not coded                                                   :  51
## Not reported                                                :   5
## Unmeasured                                                  :4321
## Unmeasured values (some measured values reported in article):  16
##
##
## Chemical.Purity                  Species.Scientific.Name
## NR     :2502    Apis mellifera              : 667
## 25     : 244    Bombus terrestris           : 183
## 50     : 200    Apis mellifera ssp. carnica  : 152
## 20     : 189    Bombus impatiens            : 140
## 70     : 112    Apis mellifera ssp. ligustica: 113
## 75     :  89    Popillia japonica           :  94
## (Other):1287    (Other)                     :3274
##            Species.Common.Name
## Honey Bee           : 667
## Parasitic Wasp      : 285
## Buff Tailed Bumblebee: 183
## Carniolan Honey Bee  : 152
## Bumble Bee          : 140
## Italian Honeybee    : 113
## (Other)             :3083
##                                                         Species.Group
## Insects/Spiders                                               :3569
## Insects/Spiders; Standard Test Species                        :  27
## Insects/Spiders; Standard Test Species; U.S. Invasive Species: 667
## Insects/Spiders; U.S. Invasive Species                        : 360
##
##
##
##   Organism.Lifestage  Organism.Age            Organism.Age.Units
## Not reported:2271     NR     :3851   Not reported        :3515
## Adult       :1222     2      : 111   Day(s)              : 327
## Larva       : 437     3      : 105   Instar              : 255
## Multiple    : 285     <24    :  81   Hour(s)             : 241
## Egg         : 128     4      :  81   Hours post-emergence:  99
## Pupa        :  69     1      :  59   Year(s)             :  64
## (Other)     : 211     (Other): 335   (Other)             : 122
##                       Exposure.Type        Media.Type
## Environmental, unspecified:1599   No substrate:2934
## Food                      :1124   Not reported: 663
## Spray                     : 393   Natural soil: 393
## Topical, general          : 254   Litter      : 264
## Ground granular           : 249   Filter paper: 230
## Hand spray                : 210   Not coded   :  51
## (Other)                   : 794   (Other)     :  88
##               Test.Location  Number.of.Doses       Conc.1.Type..Author.
## Field artificial    :  96   2      :2441    Active ingredient:3161
## Field natural       :1663   3      : 499    Formulation      :1420
## Field undeterminable:   4   5      : 314    Not coded        :  42
## Lab                 :2860   6      : 230
##                             4      : 221
```

```
##                               NR     : 217
##                               (Other): 701
##  Conc.1..Author. Conc.1.Units..Author.              Effect
##  0.37/  : 208    AI kg/ha  : 575       Population      :1803
##  10/    : 127    AI mg/L   : 298       Mortality       :1493
##  NR/    : 108    AI lb/acre: 277       Behavior        : 360
##  NR     :  94    AI g/ha   : 241       Feeding behavior: 255
##  1      :  82    ng/org    : 231       Reproduction    : 197
##  1023   :  80    ppm       : 180       Development     : 136
##  (Other):3924    (Other)   :2821       (Other)         : 379
##               Effect.Measurement    Endpoint                  Response.Site
##  Abundance              :1699     NOEL   :1816   Not reported          :4349
##  Mortality              :1294     LOEL   :1664   Midgut or midgut gland:  63
##  Survival               : 133     LC50   : 327   Not coded             :  51
##  Progeny counts/numbers: 120      LD50   : 274   Whole organism        :  41
##  Food consumption       : 103     NR     : 167   Hypopharyngeal gland  :  27
##  Emergence              :  98     NR-LETH:  86   Head                  :  23
##  (Other)                :1176     (Other): 289   (Other)               :  69
##  Observed.Duration..Days.       Observed.Duration.Units..Days.
##  1      : 713            Day(s)              :4394
##  2      : 383            Emergence           :  70
##  NR     : 355            Growing season      :  48
##  7      : 207            Day(s) post-hatch   :  20
##  3      : 183            Day(s) post-emergence:  17
##  0.0417 : 133            Tiller stage        :  15
##  (Other):2649            (Other)             :  59
##                                                                           Author
##  Peck,D.C.                                                               : 208
##  Frank,S.D.                                                              : 100
##  El Hassani,A.K., M. Dacher, V. Gary, M. Lambin, M. Gauthier, and C. Armengaud:  96
##  Williamson,S.M., S.J. Willis, and G.A. Wright                           :  93
##  Laurino,D., A. Manino, A. Patetta, and M. Porporato                     :  88
##  Scholer,J., and V. Krischik                                             :  82
##  (Other)                                                                 :3956
##  Reference.Number
##  Min.   :   344
##  1st Qu.:108459
##  Median :165559
##  Mean   :142189
##  3rd Qu.:168998
##  Max.   :180410
##
##
##  Long-Term Effects of Imidacloprid on the Abundance of Surface- and Soil-Active Nontarget Fauna in Tu
##  Reduced Risk Insecticides to Control Scale Insects and Protect Natural Enemies in the Production and
##  Effects of Sublethal Doses of Acetamiprid and Thiamethoxam on the Behavior of the Honeybee (Apis mel
##  Exposure to Neonicotinoids Influences the Motor Function of Adult Worker Honeybees
##  Toxicity of Neonicotinoid Insecticides on Different Honey Bee Genotypes
##  Chronic Exposure of Imidacloprid and Clothianidin Reduce Queen Survival, Foraging, and Nectar Storin
##  (Other)
##                                           Source      Publication.Year
##  Agric. For. Entomol.11(4): 405-419           : 200   Min.   :1982
##  Environ. Entomol.41(2): 377-386              : 100   1st Qu.:2005
##  Arch. Environ. Contam. Toxicol.54(4): 653-661:  96   Median :2010
```

```
##  Ecotoxicology23:1409-1418                      :  93   Mean   :2008
##  Bull. Insectol.66(1): 119-126                  :  88   3rd Qu.:2013
##  PLoS One9(3): 14 p.                            :  82   Max.   :2019
##  (Other)                                        :3964
##  Summary.of.Additional.Parameters
##  Purity: \xca NR - NR | Organism Age: \xca NR - NR Not reported | Conc 1 (Author): \xca Active ingred
##  Purity: \xca NR - NR | Organism Age: \xca NR - NR Not reported | Conc 1 (Author): \xca Active ingred
##  Purity: \xca NR - NR | Organism Age: \xca NR - NR Not reported | Conc 1 (Author): \xca Active ingred
##  Purity: \xca NR - NR | Organism Age: \xca NR - NR Not reported | Conc 1 (Author): \xca Active ingred
##  Purity: \xca NR - NR | Organism Age: \xca NR - NR Not reported | Conc 1 (Author): \xca Active ingred
##  Purity: \xca NR - NR | Organism Age: \xca NR - NR Not reported | Conc 1 (Author): \xca Formulation I
##  (Other)
```

```
sort(summary(Neonics$Species.Common.Name))
```

```
##                        Ant Family                      Apple Maggot
##                                 9                                 9
##           Glasshouse Potato Wasp                          Lacewing
##                                10                                10
##           Southern House Mosquito          Two Spotted Lady Beetle
##                                10                                10
##          Spotless Ladybird Beetle               Braconid Parasitoid
##                                11                                12
##                     Common Thrip      Eastern Subterranean Termite
##                                12                                12
##                           Jassid                        Mite Order
##                                12                                12
##                        Pea Aphid                  Pond Wolf Spider
##                                12                                12
##             Armoured Scale Family                 Diamondback Moth
##                                13                                13
##                     Eulophid Wasp                 Monarch Butterfly
##                                13                                13
##                    Predatory Bug             Yellow Fever Mosquito
##                                13                                13
##                     Corn Earworm                 Green Peach Aphid
##                                14                                14
##                        House Fly                         Ox Beetle
##                                14                                14
##               Red Scale Parasite                Spined Soldier Bug
##                                14                                14
##            Western Flower Thrips Hemlock Woolly Adelgid Lady Beetle
##                                15                                16
##              Hemlock Wooly Adelgid                            Mite
##                                16                                16
##                      Onion Thrip             Araneoid Spider Order
##                                16                                17
##                        Bee Order                   Egg Parasitoid
##                                17                                17
##                     Insect Class          Moth And Butterfly Order
##                                17                                17
##      Oystershell Scale Parasitoid          Black-spotted Lady Beetle
##                                17                                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
##           Codling Moth   Flatheaded Appletree Borer
##                     19                           20
##    Horned Oak Gall Wasp            Leaf Beetle Family
##                     20                           20
##       Potato Leafhopper   Tooth-necked Fungus Beetle
##                     20                           20
##          Argentine Ant                        Beetle
##                     21                           21
##              Mason Bee                      Mosquito
##                     22                           22
##       Citrus Leafminer               Ladybird Beetle
##                     23                           23
##       Spider/Mite Class           Tobacco Flea Beetle
##                     24                           24
##           Chalcid Wasp       Convergent Lady Beetle
##                     25                           25
##          Stingless Bee          Ground Beetle Family
##                     25                           27
##      Rove Beetle Family                Tobacco Aphid
##                     27                           27
##          Scarab Beetle                 Spring Tiphia
##                     29                           29
##            Thrip Order       Ladybird Beetle Family
##                     29                           30
##             Parasitoid                 Braconid Wasp
##                     30                           33
##           Cotton Aphid                Predatory Mite
##                     33                           33
##    Sweetpotato Whitefly                  Aphid Family
##                     37                           38
##         Cabbage Looper         Buff-tailed Bumblebee
##                     38                           39
##         True Bug Order       Sevenspotted Lady Beetle
##                     45                           46
##           Beetle Order   Snout Beetle Family, Weevil
##                     47                           47
##      Erythrina Gall Wasp               Parasitoid Wasp
##                     49                           51
##   Colorado Potato Beetle                Parastic Wasp
##                     57                           58
##     Asian Citrus Psyllid             Minute Pirate Bug
##                     60                           62
##       European Dark Bee                      Wireworm
##                     66                           69
##         Euonymus Scale             Asian Lady Beetle
##                     75                           76
##        Japanese Beetle              Italian Honeybee
```

```
##                                   94                                  113
##                           Bumble Bee                   Carniolan Honey Bee
##                                  140                                  152
##                 Buff Tailed Bumblebee                      Parasitic Wasp
##                                  183                                  285
##                            Honey Bee                              (Other)
##                                  667                                  670
```

Answer: The 6 most commonly studied species are the Honey Bee, Parisitic Wasp, Buff Tailed Bumble Bee, Carniolan Honey Bee, Bumble Bee and Italian Honeybee. All of these species fall under the order Hymenoptera.Compared to the other species listed, they are all common pollinators except for the Paristic Wasp making them of high environmental relevance.

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?

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

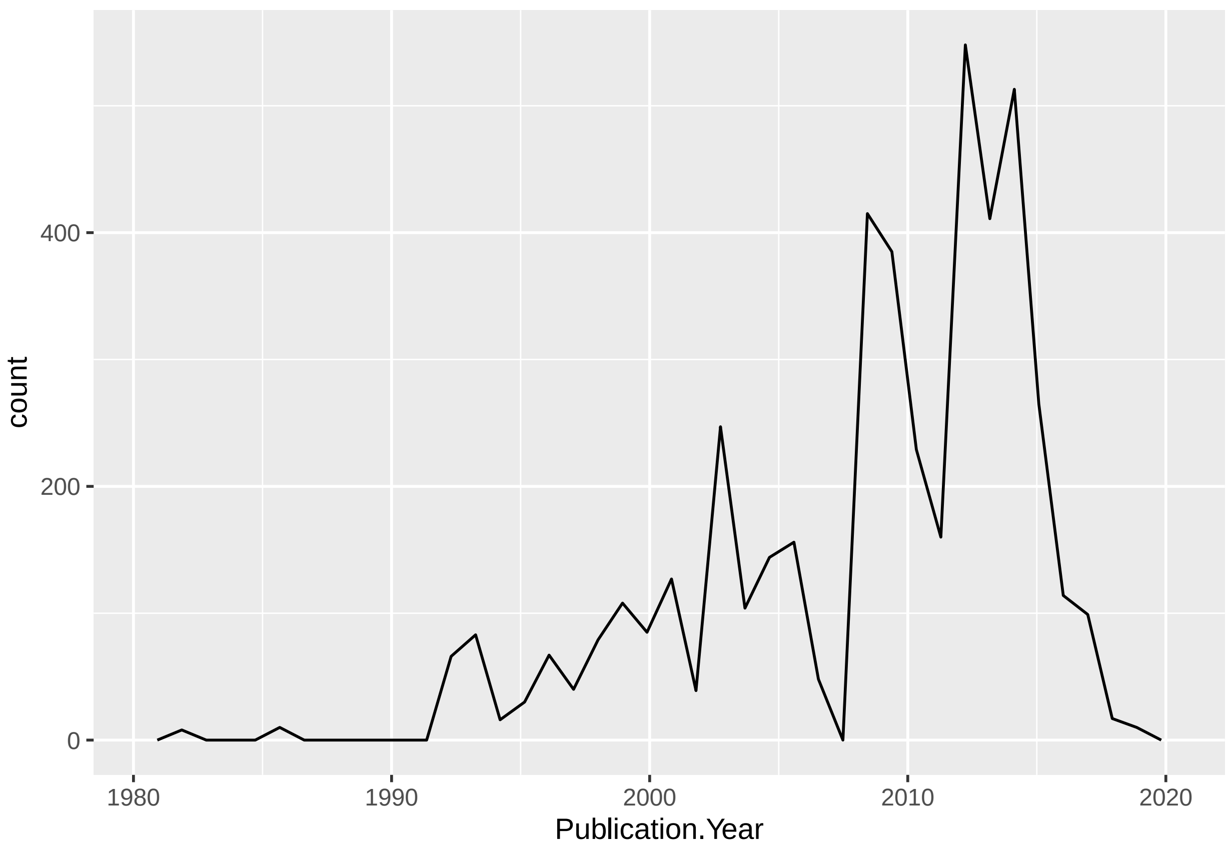
```
## [1] "factor"
```

Answer: It is not numeric because the data consists of slashes or NAs that are non numeric.This would be defined as characters but since we wrote in stringsAsFactors <- TRUE, the class is a factor.

## Explore your data graphically (Neonics)

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

```
ggplot(Neonics) + geom_freqpoly(aes(x=Publication.Year),bins=40)
```



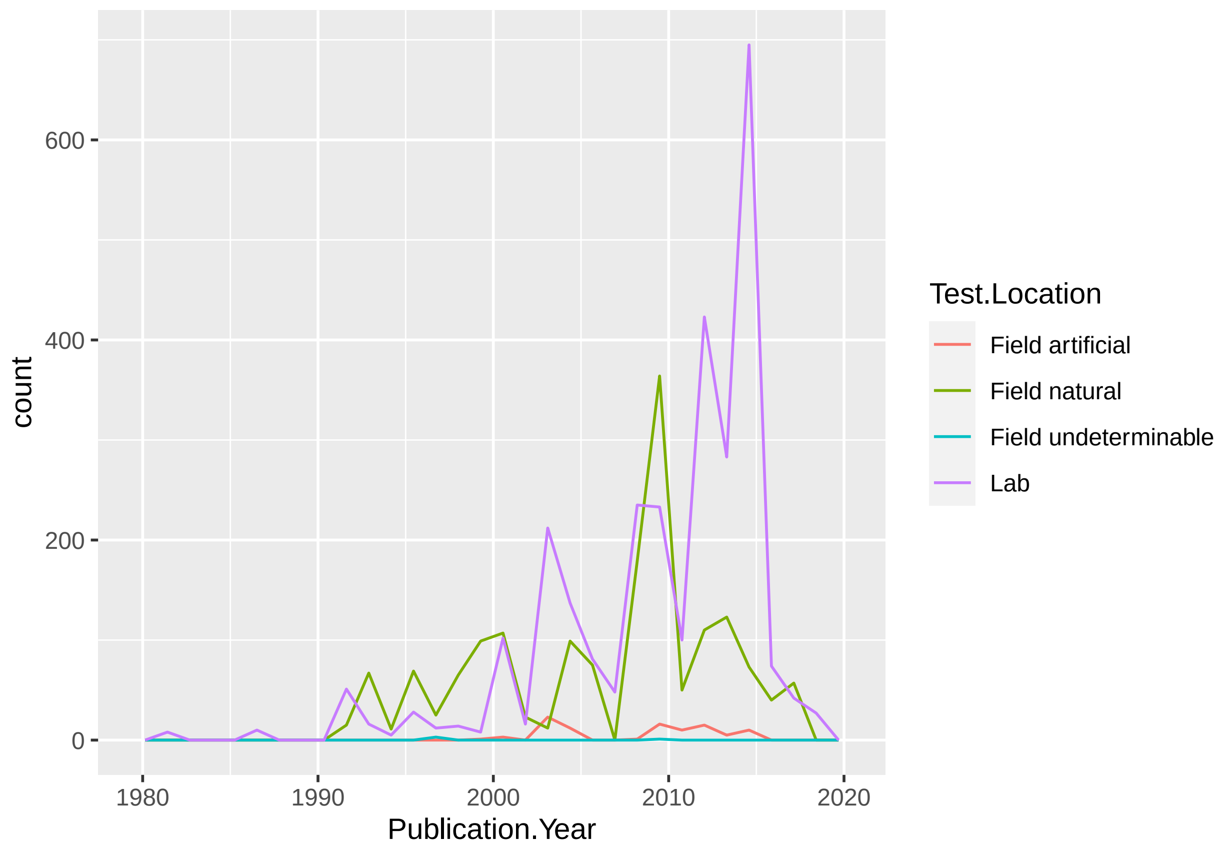

```
#the bins impact how much data is shown in the plot
```

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

```
ggplot(Neonics) + geom_freqpoly(aes(x= Publication.Year,color= Test.Location,bins=40))
```

```
## Warning in geom_freqpoly(aes(x = Publication.Year, color = Test.Location, :
## Ignoring unknown aesthetics: bins
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```




```
#color allows two types of data to be shown in one graph. Field sites are categorical data.
```

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

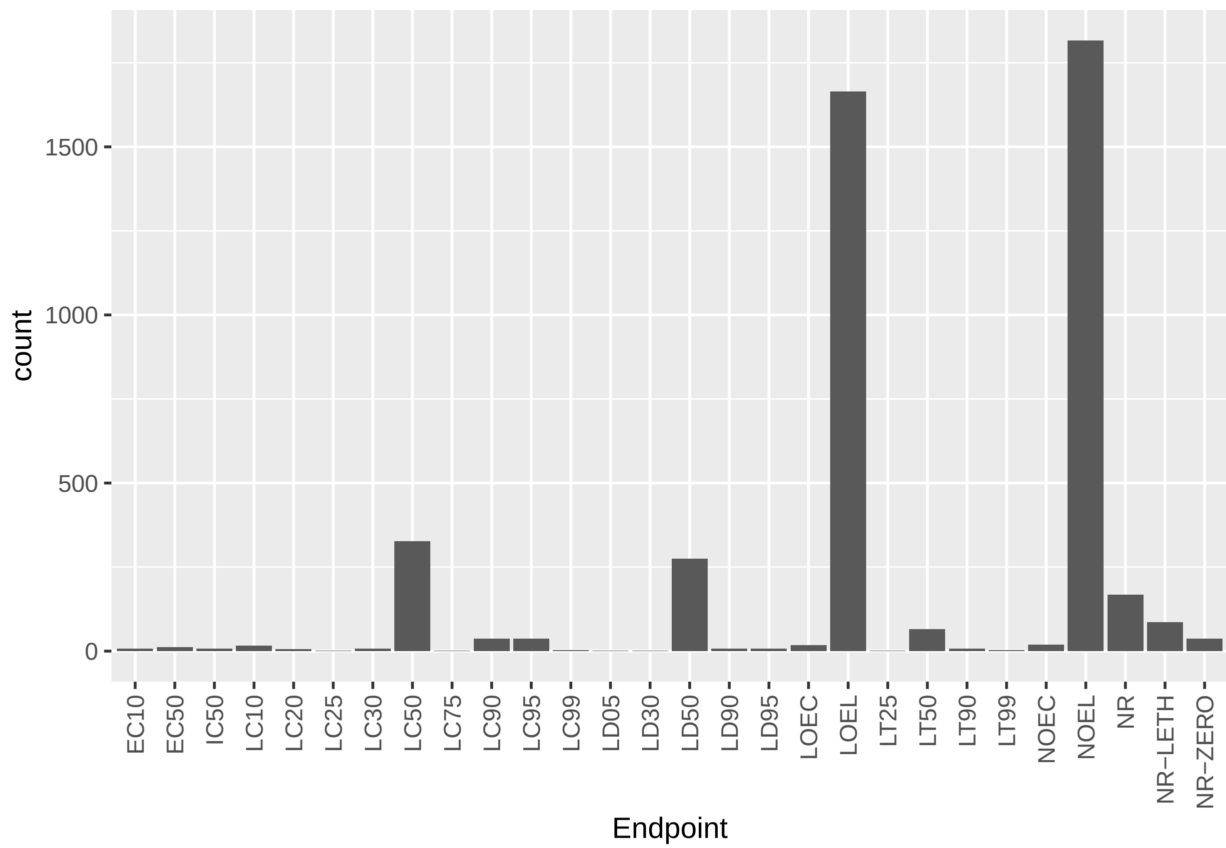
> Answer: The most common overall test location is the Lab.This has fluctuated and changed over time, where in 2010 a natural field site was the most common location. Between 2010 and 2020 there was a steep increase in Lab sites with a decline in Natural Test location. Until the 2000s, natural test sites were more common than Labs. Field Artificial and Field undeterminable have been used infrequently in comparison.

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…]

```
ggplot(Neonics) + geom_histogram(aes(x=Endpoint),stat="count") + theme(axis.text.x = element_text(angle
```

```
## Warning in geom_histogram(aes(x = Endpoint), stat = "count"): Ignoring unknown
## parameters: `binwidth`, `bins`, and `pad`
```




Answer: The two most common endpoints are NOEL and LOEL. NOEL stands for No Observable Effect Level and LOEL stands for Lowest Observable Effect Level. LOEL refers to the lowest dose at which an effect is seen, that is observably or significantly different than the control.NOEL is the highest dose at which no effects are seen that are observably or significantly different than the control.

## 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] "factor"
```

```
library(lubridate)
class(Litter$collectDate)
```

```
## [1] "factor"
```

```
date_new <- ymd(Litter$collectDate)


class(date_new)
```

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

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

```
unique(Litter$plotID)
```

```
##  [1] NIWO_061 NIWO_064 NIWO_067 NIWO_040 NIWO_041 NIWO_063 NIWO_047 NIWO_051
##  [9] NIWO_058 NIWO_046 NIWO_062 NIWO_057
## 12 Levels: NIWO_040 NIWO_041 NIWO_046 NIWO_047 NIWO_051 NIWO_057 ... NIWO_067
```

```
summary(Litter$plotID)
```

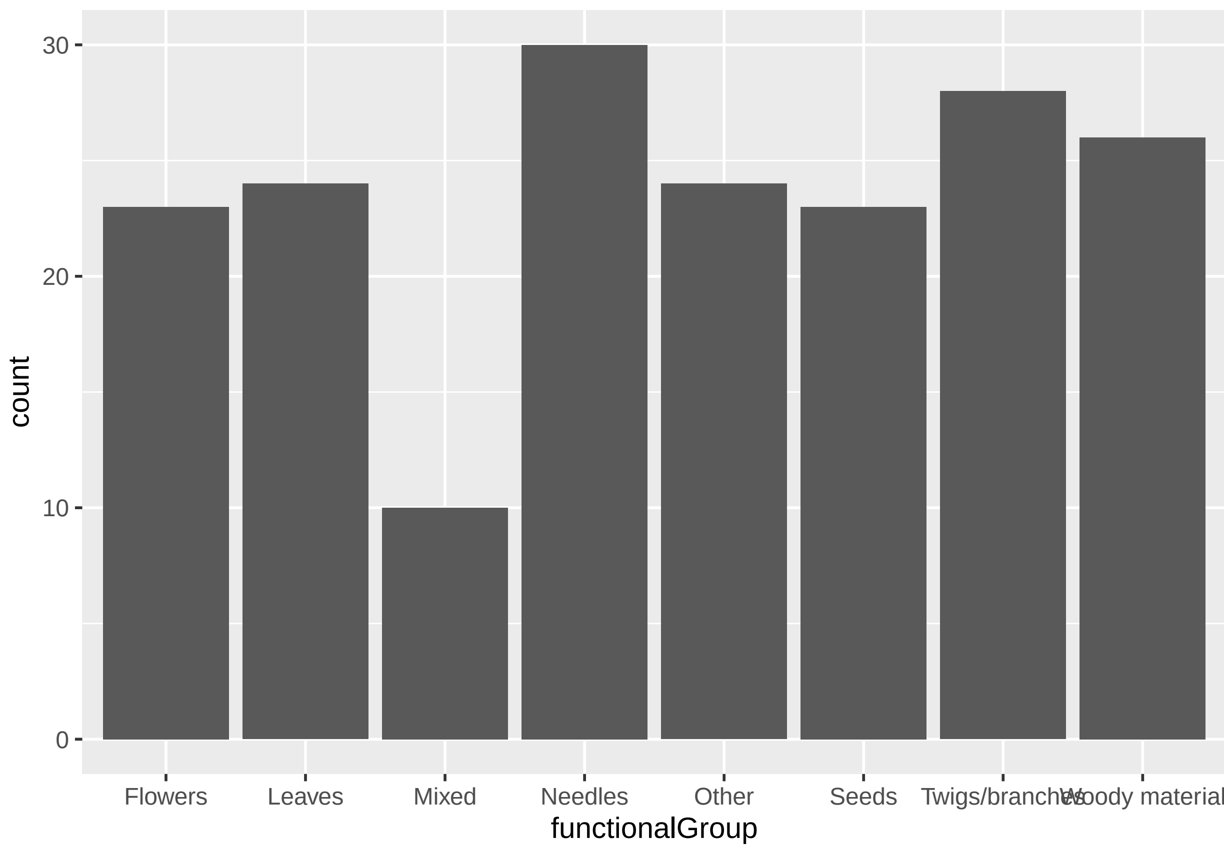
```
## NIWO_040 NIWO_041 NIWO_046 NIWO_047 NIWO_051 NIWO_057 NIWO_058 NIWO_061
##       20       19       18       15       14        8       16       17
## NIWO_062 NIWO_063 NIWO_064 NIWO_067
##       14       14       16       17
```

> Answer: There are 12 plots sampled at Niwot Ridge. In this scenario, the summary function tells us how many times each of the plot IDs are mentioned whereas the unique function only displays the first time each of the plot ID's come up instead of listing how many times they appear.

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.

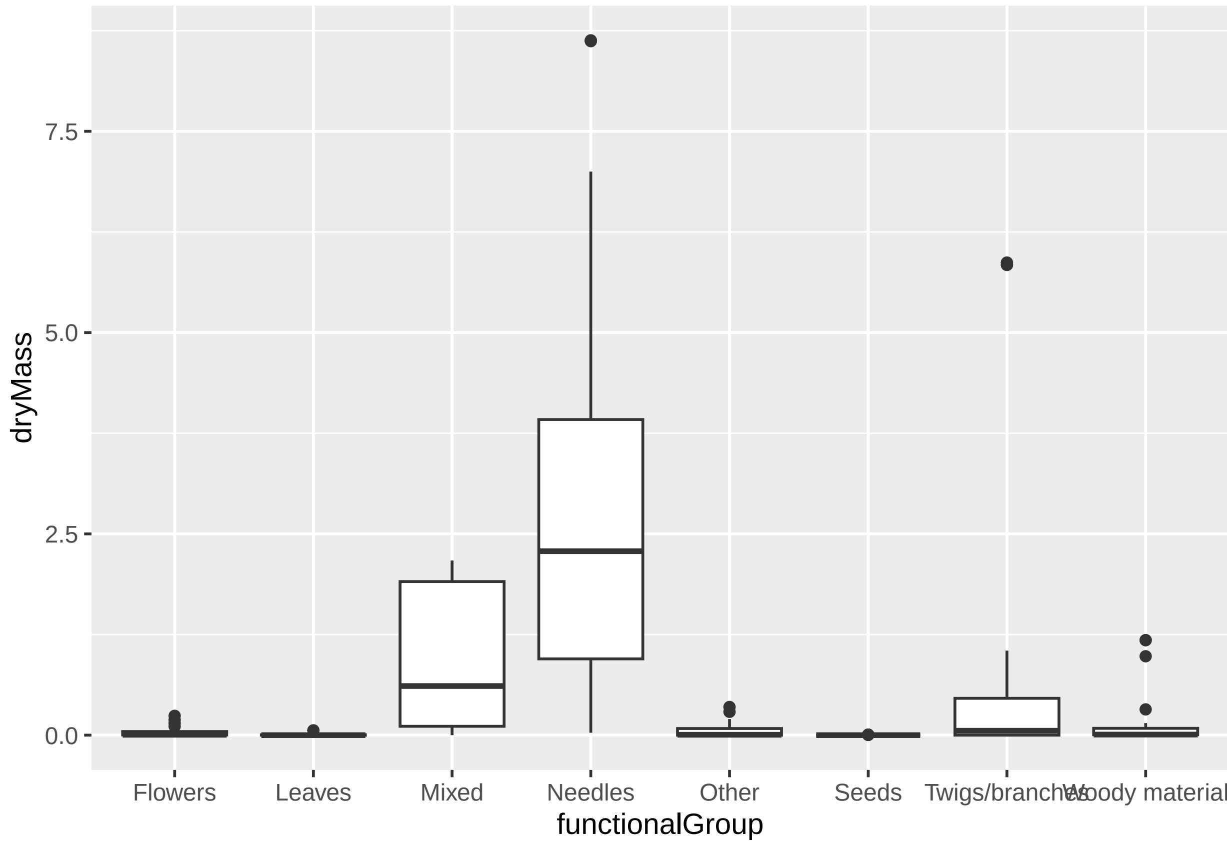
```
ggplot(Litter) + geom_histogram(aes(x=functionalGroup),stat="count")
```

```
## Warning in geom_histogram(aes(x = functionalGroup), stat = "count"): Ignoring
## unknown parameters: ‘binwidth‘, ‘bins‘, and ‘pad‘
```

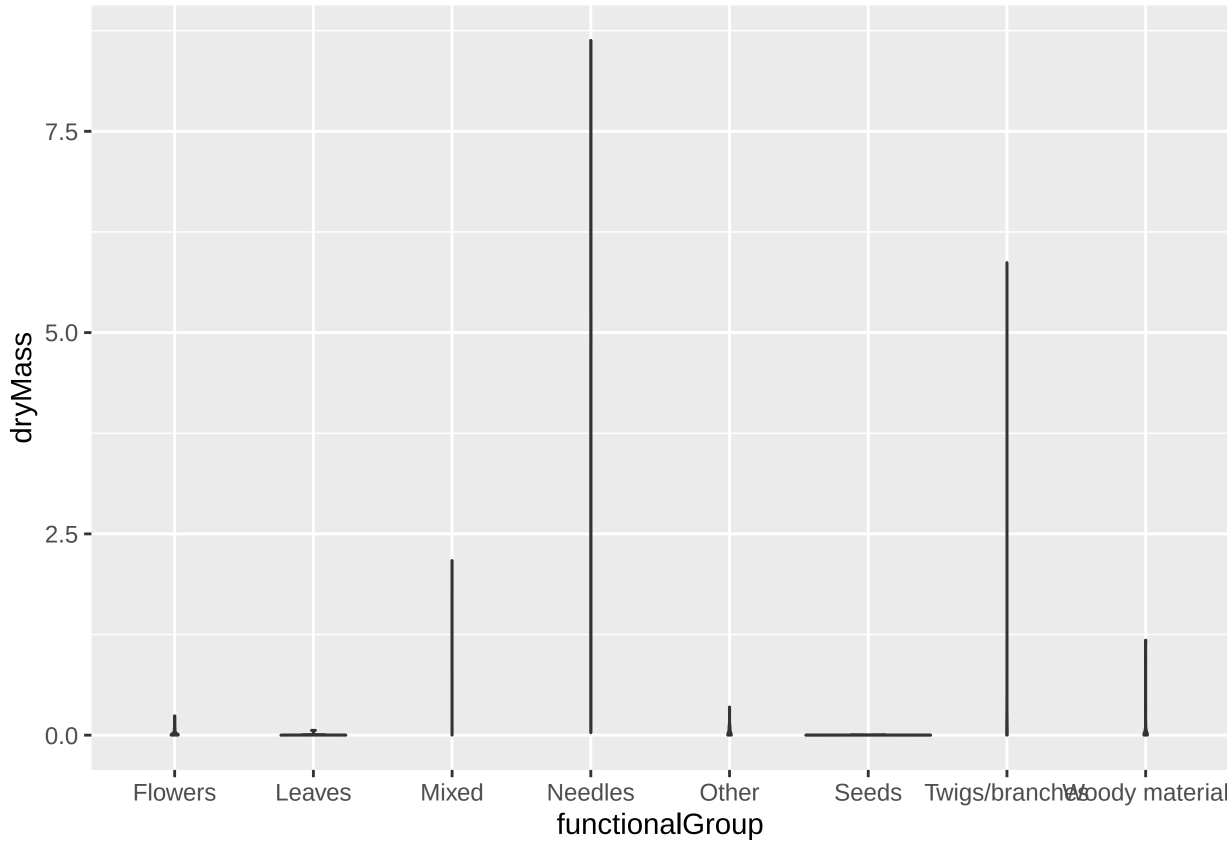



15. Using `geom_boxplot` and `geom_violin`, create a boxplot and a violin plot of dryMass by functionalGroup.

```
ggplot(Litter) + geom_boxplot(aes(x=functionalGroup,y=dryMass))
```




```
ggplot(Litter) + geom_violin(aes(x=functionalGroup,y=dryMass),draw_quantiles =c(0.25,0.5,0.75))
```




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

> Answer: The boxplot is a more effective visualization option in this case compared to the violin plot. This may be occurring because the range and outliers are concentrating the drymass values at lower values, making it hard to see the spread of data. Another possibility is that the data itself doesn't have much variation so the violin plot isn't giving us any insight. In contrast, a boxplot captures summary statistics and an idea of the data spread. However, a boxplot gives a spread of data in reference to the IQR whereas a violin plot gives us more information regarding normal distribution relative to the data itself.

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.The mean and maximum of needle dry mass is higher than Mixed or Twigs/Branches which also have higher biomasses compared to the rest of the categories.