Opioid-Related Death in Massachusetts

Simulated Demo

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```
#### Packages ####
library(tidyverse)
# Loads: ggplot2, dplyr, tidyr, readr, purrr, tibble, stringr, & forcats
library(tigris)
library(lubridate)
library(knitr)
library(kableExtra)
library(grid)
library(gridExtra)
library(extrafont)
library(viridis)

#### External Data ####
# base shp file for mapping
shp<-zctas(year=2010,state="Massachusetts")
# Example occupations and industries
occups<-read_csv("Occups.csv")
# ICD10 2018 codes
# Source: https://www.cms.gov/Medicare/Coding/ICD10/2018-ICD-10-CM-and-GEMs.html
icd10<-read_csv("icd10cm_order_2018.csv")
```

Data Set Unification

This project made use of publicly available death records of individuals who died in Massachusetts, USA between 2000 and 2017 with an opioid-related ICD10 code assigned to them as a cause of death. The data source presented several challenges, not least among them, errors due to manual entry of information. However, the greatest hurdle were changes to data format in mid-2014. Prior to that 2014 format change, 77 variables were available. After the format change, a staggering 843 were available. While the vast majority of the earlier variables were repeated in the newer format, both variable names and coding structures were updated. In order to fit any sort of temporal model, we needed a unified data set. Additionally, while we were interested in several individual-level covariates, much of these data were irrelevant to us. I developed the following functions as a mechanism to extract specific information from the raw vitals, recode it, and populate a data frame much more suited to the project's needs. Note that these functions create coded data sets. The full data included several hundred thousand observations. The coding was a mechanism meant to reduce file size for sharing between colleagues. The analysis was actually completed using data run through another function which converted the numeric labels to their representative values.

```
#### For deaths 2000-mid 2014 ####
vital.00.14<-function(dataset){
  temp<-list()
  state<-c("ALABAMA","ALASKA","ARIZONA","ARKANSAS","CALIFORNIA","COLORADO",
           "CONNECTICUT","DELAWARE","FLORIDA","GEORGIA","HAWAII","IDAHO",
           "ILLINOIS","INDIANA","IOWA","KANSAS","KENTUCKY","LOUISIANA",
           "MAINE","MARYLAND","MASSACHUSETTS","MICHIGAN","MINNESOTA",
```

```
          "MISSISSIPPI","MISSOURI","MONTANA","NEBRASKA","NEVADA",
          "NEW HAMPSHIRE","NEW JERSEY","NEW MEXICO","NEW YORK",
          "NORTH CAROLINA","NORTH DAKOTA","OHIO","OKLAHOMA","OREGON",
          "PENNSYLVANIA","RHODE ISLAND","SOUTH CAROLINA","SOUTH DAKOTA",
          "TENNESSEE","TEXAS","UTAH","VERMONT","VIRGINIA","WASHINGTON",
          "WASHINGTON DC","WEST VIRGINIA","WISCONSIN","WYOMING")
abbr<-c("AL","AK","AZ","AR","CA","CO","CT","DC","DE","FL","GA","HI","ID",
        "IL","IN","IA","KS","KY","LA","ME","MD","MA","MI","MN","MS","MO",
        "MT","NE","NV","NH","NJ","NM","NY","NC","ND","OH","OK","OR","PA","RI",
        "SC","SD","TN","TX","UT","VT","VA","WA","WV","WI","WY")
# batch
temp$batch<-1
for(j in 1:nrow(dataset)){
  # sfnum
  temp$sfnum[j]<-unlist(dataset[j,"CERT"])
  # ddate
  temp$ddate[j]<-paste0(str_sub(dataset[j,"DOD"],1,4),"-",
                                str_sub(dataset[j,"DOD"],5,6),"-",
                                str_sub(dataset[j,"DOD"],7,8))
  # male
  if(dataset[j,"SEX"]=="1"){temp$male[j]<-1}
  if(dataset[j,"SEX"]=="2"){temp$male[j]<-0}
  # age
  if(str_sub(dataset[j,"AGE_AT_DEATH"],1,1)==0|
     str_sub(dataset[j,"AGE_AT_DEATH"],1,1)==1)
  {temp$age[j]<-as.numeric(str_sub(dataset[j,"AGE_AT_DEATH"],-2,-1))}
  else{if(str_sub(dataset[j,"AGE_AT_DEATH"],1,1)==2|
          str_sub(dataset[j,"AGE_AT_DEATH"],1,1)==4|
          str_sub(dataset[j,"AGE_AT_DEATH"],1,1)==5|
          str_sub(dataset[j,"AGE_AT_DEATH"],1,1)==6)
    {temp$age[j]<-0}else{if(str_sub(dataset[j,"AGE_AT_DEATH"],1,1)==9){temp$age[j]<-NA}}}
  # race
  if(!(dataset[j,"DETHNIC_HISPANIC"]=="0"|dataset[j,"DETHNIC_HISPANIC"]=="9"))
    {temp$race[j]<-3}
    else{if(dataset[j,"RACE"]=="01"){temp$race[j]<-1}
         if(dataset[j,"RACE"]=="02"){temp$race[j]<-2}
         if(dataset[j,"RACE"]=="03"){temp$race[j]<-5}
         if(dataset[j,"RACE"]=="04"|
            dataset[j,"RACE"]=="05"|
            dataset[j,"RACE"]=="06"|
            dataset[j,"RACE"]=="07"|
            dataset[j,"RACE"]=="08"|
            dataset[j,"RACE"]=="09"|
            dataset[j,"RACE"]=="10"|
            dataset[j,"RACE"]=="11"|
            dataset[j,"RACE"]=="12"){temp$race[j]<-4}
         if(dataset[j,"RACE"]=="13"|
            dataset[j,"RACE"]=="14"){temp$race[j]<-7}
         if(dataset[j,"RACE"]=="99"){temp$race[j]<-NA}}
  # occup
  temp$occup[j]<-unlist(dataset[j,"OCCUP"])
  # indust
  temp$indust[j]<-unlist(dataset[j,"INDUST"])
```

```
# edu
if(as.numeric(dataset[j,"DEDUC"])<=11){temp$edu[j]<-1}
  else{if(as.numeric(dataset[j,"DEDUC"])<=13){temp$edu[j]<-2}
    else{if(as.numeric(dataset[j,"DEDUC"])<=16){temp$edu[j]<-3}
      else{if(dataset[j,"DEDUC"]=="99"){temp$edu[j]<-NA}
        else{if(as.numeric(dataset[j,"DEDUC"])>16){temp$edu[j]<-4}}}}}
# immig
if(dataset[j,"NATIVITY"]=="99"){temp$immig[j]<-NA}
  else{if(as.numeric(dataset[j,"NATIVITY"])>51){temp$immig[j]<-4}
    else{temp$immig[j]<-5}}
# pimmig
ifelse(!dataset[j,"FATHER_BSTATE"]%in%state&
       !dataset[j,"FATHER_BSTATE"]%in%abbr&
       !dataset[j,"FATHER_BSTATE"]=="UNKNOWN",
       yes=ifelse(!dataset[j,"MOTHER_BSTATE"]%in%state&
                  !dataset[j,"MOTHER_BSTATE"]%in%abbr&
                  !dataset[j,"MOTHER_BSTATE"]=="UNKNOWN",
                  yes=temp$pimmig[j]<-2,
                  no=temp$pimmig[j]<-1),
       no=ifelse(!dataset[j,"MOTHER_BSTATE"]%in%state&
                 !dataset[j,"MOTHER_BSTATE"]%in%abbr&
                 !dataset[j,"MOTHER_BSTATE"]=="UNKNOWN",
                 yes=temp$pimmig[j]<-1,
                 no=ifelse((dataset[j,"FATHER_BSTATE"]%in%state|
                     dataset[j,"FATHER_BSTATE"]%in%abbr)&
                    (dataset[j,"MOTHER_BSTATE"]%in%state|
                     dataset[j,"MOTHER_BSTATE"]%in%abbr),
                    yes=temp$pimmig[j]<-0,
                    no=temp$pimmig[j]<-NA)))
# marital
if(dataset[j,"MARITAL"]=="1"){temp$marital[j]<-5}
if(dataset[j,"MARITAL"]=="2"){temp$marital[j]<-1}
if(dataset[j,"MARITAL"]=="3"){temp$marital[j]<-3}
if(dataset[j,"MARITAL"]=="4"){temp$marital[j]<-4}
if(dataset[j,"MARITAL"]=="9"){temp$marital[j]<-NA}
# veteran
if(dataset[j,"VET_STAT"]==0){temp$veteran[j]<-0}
else{if(dataset[j,"VET_STAT"]==9){temp$veteran[j]<-NA}
  else{temp$veteran[j]<-1}}
# preg
temp$preg[j]<-NA
# resadd
temp$resadd[j]<-str_remove_all(paste(dataset[j,"RES_ADDR_NUM"],
                                     dataset[j,"RES_ADDR1"],
                                     dataset[j,"RES_STREET_DESIG"]),," NA")
# rescity
temp$rescity[j]<-unlist(dataset[j,"RES_CITY"])
# resstate
ifelse(is.na(dataset[j,"RES_CITY_CODE"]),
       yes=temp$resstate[j]<-NA,
       no=ifelse(as.numeric(dataset[j,"RES_CITY_CODE"])<=351,
                 yes=temp$resstate[j]<-"MASSACHUSETTS",
                 no=temp$resstate[j]<-"OUT OF STATE"))
```

```
# reszip
temp$reszip[j]<-unlist(dataset[j,"RES_ZIP"])
# resnat
temp$resnat[j]<-NA
# dplace
ifelse(dataset[j,"DPLACE"]==1,
       yes=temp$dplace[j]<-1,
       no=ifelse(dataset[j,"DPLACE"]==2,
                 yes=temp$dplace[j]<-2,
                 no=ifelse(dataset[j,"DPLACE"]==3,
                           yes=temp$dplace[j]<-3,
                           no=ifelse(dataset[j,"DPLACE"]==5,
                                     yes=temp$dplace[j]<-6,
                                     no=ifelse(dataset[j,"DPLACE"]==6,
                                               yes=temp$dplace[j]<-4,
                                               no=ifelse(dataset[j,"DPLACE"]==7,
                                                         yes=temp$dplace[j]<-8,
                                                         no=temp$dplace[j]<-NA))))))
# dfacilitynum
if(dataset[j,"FACCODE"]=="0000"|
   dataset[j,"FACCODE"]=="0060"|
   dataset[j,"FACCODE"]=="0070"|
   dataset[j,"FACCODE"]=="0080"|
   dataset[j,"FACCODE"]=="0090"|
   dataset[j,"FACCODE"]=="9999"){temp$dfacilitynum[j]<-NA}
else{temp$dfacilitynum[j]<-unlist(dataset[j,"FACCODE"])}
# dadd
temp$ddad[j]<-NA
# dcity
temp$dcity[j]<-unlist(dataset[j,"DNAME_CITY"])
# dstate
ifelse(dataset[j,"DSTATEL"]=="MA",
       yes=temp$dstate[j]<-"MASSACHUSETTS",
       no=ifelse(dataset[j,"DSTATEL"]=="MASSACHUSETTS",
                 yes=temp$dstate[j]<-"MASSACHUSETTS",
                 no=temp$dstate[j]<-NA))
# dzip
temp$dzip[j]<-NA
# dnat
temp$dnat[j]<-"UNITED STATES"
# travel
ifelse(!is.na(dataset[j,"RES_CITY"])&!is.na(dataset[j,"DNAME_CITY"]),
       yes=ifelse(dataset[j,"RES_CITY"]==dataset[j,"DNAME_CITY"],
                  yes=temp$travel[j]<-0,
                  no=temp$travel[j]<-1),
       no=temp$travel[j]<-NA)
# All icd variables
y<-str_trim(str_split(str_replace_all(dataset[j,"TRX_REC_AXIS_CD"],"  "," "),
                      " ",simplify=T),side="both")
x<-vector(mode="character")
l<-1
for(k in 1:length(y)){
  if(str_length(y[k])>4){
```

```
      if(str_length(y[k])<6)
      {x[l]<-str_remove(y[k],".$")
      l<-l+1}
      else
      {x[l]<-str_split(y[k],"0",simplify=T)[1]
      l<-l+1
      x[l]<-str_split(y[k],"0",simplify=T)[2]
      l<-l+1}}
    else
    {x[l]<-y[k]
    l<-l+1}}
  # icd1
  if(is.na(x[1])){temp$icd1[j]<-NA}
  else{temp$icd1[j]<-x[1]}
  # icd2
  if(is.na(x[2])){temp$icd2[j]<-NA}
  else{temp$icd2[j]<-x[2]}
  # icd3
  if(is.na(x[3])){temp$icd3[j]<-NA}
  else{temp$icd3[j]<-x[3]}
  # icd4
  if(is.na(x[4])){temp$icd4[j]<-NA}
  else{temp$icd4[j]<-x[4]}
  # icd5
  if(is.na(x[5])){temp$icd5[j]<-NA}
  else{temp$icd5[j]<-x[5]}
  # icd6
  if(is.na(x[6])){temp$icd6[j]<-NA}
  else{temp$icd6[j]<-x[6]}
  # icd7
  if(is.na(x[7])){temp$icd7[j]<-NA}
  else{temp$icd7[j]<-x[7]}
  # icd8
  if(is.na(x[8])){temp$icd8[j]<-NA}
  else{temp$icd8[j]<-x[8]}
  # icd9
  if(is.na(x[9])){temp$icd9[j]<-NA}
  else{temp$icd9[j]<-x[9]}
  # icd10
  if(is.na(x[10])){temp$icd10[j]<-NA}
  else{temp$icd10[j]<-x[10]}
  # icd11
  if(is.na(x[11])){temp$icd11[j]<-NA}
  else{temp$icd11[j]<-x[11]}
  # icd12
  if(is.na(x[12])){temp$icd12[j]<-NA}
  else{temp$icd12[j]<-x[12]}
  # icd13
  if(is.na(x[13])){temp$icd13[j]<-NA}
  else{temp$icd13[j]<-x[13]}
  #icd14
  if(is.na(x[14])){temp$icd14[j]<-NA}
  else{temp$icd14[j]<-x[14]}
```

```
    # icd15
    if(is.na(x[15])){temp$icd15[j]<-NA}
    else{temp$icd15[j]<-x[15]}
    #icd16
    if(is.na(x[16])){temp$icd16[j]<-NA}
    else{temp$icd16[j]<-x[16]}
  }
  return(as_tibble(temp))
}
```

```
#### For deaths late 2014-2017 ####
vital.14.17<-function(dataset){
  temp<-list()
  # batch
  temp$batch<-2
  for(i in 1:nrow(dataset)){
    # sfnum
    temp$sfnum[i]<-unlist(dataset[i,"SFN_NUM"])
    # ddate
    temp$ddate[i]<-paste0(str_sub(dataset[i,"DOD_4_FD"],7,10),"-",
                          str_sub(dataset[i,"DOD_4_FD"],1,2),"-",
                          str_sub(dataset[i,"DOD_4_FD"],4,5))
    # male
    ifelse(dataset[i,"SEX"]=="M",
           yes=temp$male[i]<-1,
           no=ifelse(dataset[i,"SEX"]=="F",
                     yes=temp$male[i]<-0,
                     no=temp$male[i]<-NA))
    # age
    if(dataset[i,"AGETYPE"]==1)
    {temp$age[i]<-unlist(dataset[i,"AGE1_CALC"])}
    else{if(dataset[i,"AGETYPE"]==2|
            dataset[i,"AGETYPE"]==3)
    {temp$age[i]<-0}
      else{if(dataset[i,"AGETYPE"]==8|
              dataset[i,"AGETYPE"]==9)
      {temp$age[i]<-NA}}}
    # race
    ifelse(str_count(paste0(dataset[i,"RACE1"],
                            dataset[i,"RACE_AM_NATIVE"],
                            dataset[i,"RACE_ASIAN"],
                            dataset[i,"RACE_BLACK"],
                            dataset[i,"DETHNIC4"]),"Y")>1,
           yes=temp$race[i]<-6,
           no=ifelse(dataset[i,"RACE_HISP_LAT_WHITE"]=="Y"|
                     dataset[i,"RACE_HISP_LAT_BLACK"]=="Y"|
                     dataset[i,"DETHNIC4"]=="Y",
                     yes=temp$race[i]<-3,
                     no=ifelse(dataset[i,"RACE1"]=="Y",
                               yes=temp$race[i]<-1,
                               no=ifelse(dataset[i,"RACE_BLACK"]=="Y",
                                         yes=temp$race[i]<-2,
                                         no=ifelse(dataset[i,"RACE_ASIAN"]=="Y",
                                                   yes=temp$race[i]<-4,
                                                   no=ifelse(dataset[i,"RACE_AM_NATIVE"]=="Y",
                                                             yes=temp$race[i]<-5,
                                                             no=ifelse(dataset[i,"RACE_UNK"]=="Y",
                                                                       yes=temp$race[i]<-NA,
                                                                       no=temp$race[i]<-7)))))))
    # occup
    temp$occup[i]<-unlist(dataset[i,"OCCUP"])
    # indust
    temp$indust[i]<-unlist(dataset[i,"INDUST"])
```

```
    # edu
    ifelse(dataset[i,"DEDUC"]==1|
           dataset[i,"DEDUC"]==2,
           yes=temp$edu[i]<-1,
           no=ifelse(dataset[i,"DEDUC"]==3|
                     dataset[i,"DEDUC"]==4|
                     dataset[i,"DEDUC"]==5,
                     yes=temp$edu[i]<-2,
                     no=ifelse(dataset[i,"DEDUC"]==6|
                               dataset[i,"DEDUC"]==7,
                               yes=temp$edu[i]<-3,
                               no=ifelse(dataset[i,"DEDUC"]==8|
                                         dataset[i,"DEDUC"]==9,
                                         yes=temp$edu[i]<-4,
                                         no=ifelse(dataset[i,"DEDUC"]==12,
                                                   yes=temp$edu[i]<-5,
                                                   no=temp$edu[i]<-NA)))))
    # immig
    ifelse(dataset[i,"RES_COUNTRY"]=="UNITED STATES",
           yes=ifelse(dataset[i,"BPLACE_CNT"]=="UNITED STATES",
                      yes=temp$immig[i]<-0,
                      no=temp$immig[i]<-1),
           no=ifelse(dataset[i,"BPLACE_CNT"]=="UNITED STATES",
                     yes=temp$immig[i]<-3,
                     no=temp$immig[i]<-2))
    # pimmig
    ifelse(!(dataset[i,"FATHER_BCOUNTRY"]=="UNITED STATES"|
           dataset[i,"FATHER_BCOUNTRY"]=="UNKNOWN"),
           yes=ifelse(!(dataset[i,"MOTHER_BCOUNTRY"]=="UNITED STATES"|
                      dataset[i,"MOTHER_BCOUNTRY"]=="UNKNOWN"),
                      yes=temp$pimmig[i]<-2,
                      no=temp$pimmig[i]<-1),
           no=ifelse(!(dataset[i,"MOTHER_BCOUNTRY"]=="UNITED STATES"|
                     dataset[i,"MOTHER_BCOUNTRY"]=="UNKNOWN"),
                     yes=temp$pimmig[i]<-1,
                     no=ifelse(dataset[i,"FATHER_BCOUNTRY"]=="UNITED STATES"&
                               dataset[i,"MOTHER_BCOUNTRY"]=="UNITED STATES",
                               yes=temp$pimmig[i]<-0,
                               no=temp$pimmig[i]<-NA)))
    # marital
    ifelse(dataset[i,"MARITAL"]=="M"|
           dataset[i,"MARITAL"]=="A",
           yes=temp$marital[i]<-1,
           no=ifelse(dataset[i,"MARITAL"]=="W",
                     yes=temp$marital[i]<-3,
                     no=ifelse(dataset[i,"MARITAL"]=="D",
                               yes=temp$marital[i]<-4,
                               no=ifelse(dataset[i,"MARITAL"]=="S",
                                         yes=temp$marital[i]<-5,
                                         no=temp$marital[i]<-NA))))
    # veteran
    ifelse(dataset[i,"ARMED"]=="Y",
           yes=temp$veteran[i]<-1,
```

```
          no=ifelse(dataset[i,"ARMED"]=="N",
                    yes=temp$veteran[i]<-0,
                    no=temp$veteran[i]<-NA))
  # preg
  if(is.na(dataset[i,"PREG"])){temp$preg[i]<-NA}
  else{if(dataset[i,"PREG"]==1){temp$preg[i]<-0}
  else{if(dataset[i,"PREG"]==2){temp$preg[i]<-1}
       else{if(dataset[i,"PREG"]==3|dataset[i,"PREG"]==4){temp$preg[i]<-2}
         else{temp$preg[i]<-NA}}}}
# resadd
temp$resadd[i]<-str_remove_all(paste(dataset[i,"RES_ADDR_NUM"],
                                     dataset[i,"RES_STREET_PREFIX"],
                                     dataset[i,"RES_ADDR1"],
                                     dataset[i,"RES_STREET_DESIG"],
                                     dataset[i,"RES_STREET_SUFFIX"],
                                     dataset[i,"RES_ADDR2"]),
                               " NA")
# rescity
temp$rescity[i]<-unlist(dataset[i,"RES_CITY"])
# resstate
temp$resstate[i]<-unlist(dataset[i,"RES_STATE"])
# reszip
temp$reszip[i]<-unlist(dataset[i,"RES_ZIP"])
# resnat
temp$resnat[i]<-unlist(dataset[i,"RES_COUNTRY"])
# dplace
ifelse(dataset[i,"DPLACE"]==9,
       yes=temp$dplace[i]<-NA,
       no=temp$dplace[i]<-unlist(dataset[i,"DPLACE"]))
# dfacilitynum
temp$dfacilitynum[i]<-unlist(dataset[i,"DFACILITYL"])
# dadd
temp$ddad[i]<-str_remove_all(paste(dataset[i,"DADDR_NUM"],
                                   dataset[i,"DSTREET_PREFIX"],
                                   dataset[i,"DADDR1"],
                                   dataset[i,"DSTREET_DESIG"],
                                   dataset[i,"DSTREET_SUFFIX"],
                                   dataset[i,"DADDR2"]),
                             " NA")
# dcity
temp$dcity[i]<-unlist(dataset[i,"DNAME_CITY"])
# dstate
temp$dstate[i]<-unlist(dataset[i,"DSTATEL"])
# dzip
temp$dzip[i]<-str_extract(dataset[i,"DZIP9"],"^.{5}")
# dnat
temp$dnat[i]<-unlist(dataset[i,"DCOUNTRY"])
# travel
ifelse(!is.na(dataset[i,"DNAME_CITY"])&
       !is.na(dataset[i,"RES_CITY"]),
       yes=ifelse(!dataset[i,"DNAME_CITY"]==dataset[i,"RES_CITY"],
                  yes=temp$travel[i]<-1,
                  no=temp$travel[i]<-0),
```

```
       no=temp$travel[i]<-NA)
# icd1
z<-str_trim(str_split(str_replace_all(dataset[i,"TRX_REC_AXIS_CD"],"  "," "),
                      " ",simplify=T),side="both")
y<-vector(mode="character")
l<-1
for(k in 1:length(z)){
  if(str_length(z[k])>4){
    if(str_length(z[k])<6)
    {y[l]<-str_remove(z[k],".$")
    l<-l+1}
    else
    {y[l]<-str_split(z[k],"0",simplify=T)[1]
    l<-l+1
    y[l]<-str_split(z[k],"0",simplify=T)[2]
    l<-l+1}}
  else
  {y[l]<-z[k]
  l<-l+1}}
if(is.na(y[1])){temp$icd1[i]<-NA}
else{temp$icd1[i]<-y[1]}
# icd2
if(is.na(y[2])){temp$icd2[i]<-NA}
else{temp$icd2[i]<-y[2]}
# icd3
if(is.na(y[3])){temp$icd3[i]<-NA}
else{temp$icd3[i]<-y[3]}
# icd4
if(is.na(y[4])){temp$icd4[i]<-NA}
else{temp$icd4[i]<-y[4]}
# icd5
if(is.na(y[5])){temp$icd5[i]<-NA}
else{temp$icd5[i]<-y[5]}
# icd6
if(is.na(y[6])){temp$icd6[i]<-NA}
else{temp$icd6[i]<-y[6]}
# icd7
if(is.na(y[7])){temp$icd7[i]<-NA}
else{temp$icd7[i]<-y[7]}
# icd8
if(is.na(y[8])){temp$icd8[i]<-NA}
else{temp$icd8[i]<-y[8]}
# icd9
if(is.na(y[9])){temp$icd9[i]<-NA}
else{temp$icd9[i]<-y[9]}
# icd10
if(is.na(y[10])){temp$icd10[i]<-NA}
else{temp$icd10[i]<-y[10]}
# icd11
if(is.na(y[11])){temp$icd11[i]<-NA}
else{temp$icd11[i]<-y[11]}
# icd12
if(is.na(y[12])){temp$icd12[i]<-NA}
```

```
  else{temp$icd12[i]<-y[12]}
  # icd13
  if(is.na(y[13])){temp$icd13[i]<-NA}
  else{temp$icd13[i]<-y[13]}
  #icd14
  if(is.na(y[14])){temp$icd14[i]<-NA}
  else{temp$icd14[i]<-y[14]}
  # icd15
  if(is.na(y[15])){temp$icd15[i]<-NA}
  else{temp$icd15[i]<-y[15]}
  #icd16
  if(is.na(y[16])){temp$icd16[i]<-NA}
  else{temp$icd16[i]<-y[16]}
  }
  return(as_tibble(temp))
}
```

Simulated Data

Individual Data Set

The following data set mimics that created by the above functions.

```
#### Preparing occupation data ####
occup<-occups%>%
  transmute(var=map2_chr(.x=occup,.y=indust,.f=~paste(.x,.y,sep=";")))
occup<-sample(occup[[1]],500,replace=T)
occup<-data.frame(occup)%>%
  separate(occup, into=c("occup","indust"),sep=";")

#### Subsetting icd10 codes ####
# To replicate repetition in actual data set
icd10<-sample_n(icd10[icd10$Header==1,],20000)

#### Coded data ####
# For reproducability
set.seed(8282019)

ind<-data.frame(
  batch=sample(c(1,2),500,replace=T),
  sfnum=sample(0:999999,500,replace=F),
  ddate=sample(seq(as.Date("2000-01-01"),as.Date("2017-12-31"),by="day"),500,replace=T),
  male=sample(0:1,500,replace=T),
  age=sample(0:100,500,replace=T),
  race=sample(1:7,500,replace=T),
  occup=occup$occup,
  indust=occup$indust,
  edu=sample(1:5,500,replace=T),
  immig=sample(0:4,500,replace=T),
  pimmig=sample(0:2,500,replace=T),
  marital=sample(c(1,3:5),500,replace=T),
  veteran=sample(0:1,500,replace=T),
  preg=sample(0:2,500,replace=T),
  resadd="1234 CIRCLE ST",
  rescity= "ANYTOWN",
  resstate= "MASSACHUSETTS",
  reszip=sample(shp@data$ZCTA5CE10,500,replace=T),
  resnat="UNITED STATES",
  dplace=sample(1:8,500,replace=T),
  dfacilitynum="000000",
  ddad="1234 SQUARE ST",
  dcity="ANYTOWN",
  dstate="MASSACHUSETTS",
  dzip=sample(shp@data$ZCTA5CE10,500,replace=T),
  dnat="UNITED STATES",
  travel=sample(0:1,500,replace=T),
  icd1=sample(icd10$ICD10Code,500,replace=T),
  icd2=sample(icd10$ICD10Code,500,replace=T),
  icd3=sample(icd10$ICD10Code,500,replace=T),
  icd4=sample(icd10$ICD10Code,500,replace=T),
  icd5=sample(icd10$ICD10Code,500,replace=T),
```

```
  icd6=sample(icd10$ICD10Code,500,replace=T),
  icd7=sample(icd10$ICD10Code,500,replace=T),
  icd8=sample(icd10$ICD10Code,500,replace=T),
  icd9=sample(icd10$ICD10Code,500,replace=T),
  icd10=sample(icd10$ICD10Code,500,replace=T),
  icd11=sample(icd10$ICD10Code,500,replace=T),
  icd12=sample(icd10$ICD10Code,500,replace=T),
  icd13=sample(icd10$ICD10Code,500,replace=T),
  icd14=sample(icd10$ICD10Code,500,replace=T),
  icd15=sample(icd10$ICD10Code,500,replace=T),
  icd16=sample(icd10$ICD10Code,500,replace=T))

#### Factored data ####
ind.f<-ind%>%
  # Changing coding to descriptive factors
  mutate(batch=factor(batch,levels=c(1:2)),
         male=factor(male,levels=c(0:1),labels=c("FEMALE","MALE")),
         race=factor(race,levels=c(1:7),
                     labels=c("NON-HISPANIC WHITE",
                              "NON-HISPANIC BLACK",
                              "HISPANIC / LATINO",
                              "ASIAN",
                              "NATIVE AMERICAN / AMERICAN INDIAN / ALASKA NATIVE",
                              "MULTI-RACIAL",
                              "OTHER")),
         edu=factor(edu,levels=c(1:5),
                    labels=c("LESS THAN HIGHSCHOOL",
                             "HIGH SCHOOL / GED / CERTIFICATE / SOME COLLEGE",
                             "BACHELOR'S / ASSOCIATE'S DEGREE",
                             "MASTER'S DEGREE OR HIGHER",
                             "SPECIAL EDUCATION")),
         immig=factor(immig,levels=c(0:4),
                      labels=c("BORN AND LIVE IN US",
                               "BORN ELSEWHERE AND LIVE IN US",
                               "BORN ELSEWHERE AND LIVE ELSEWHERE",
                               "BORN IN US AND LIVE ELSEWHERE",
                               "BORN ELSEWHERE")),
         pimmig=factor(pimmig,levels=c(0:2),
                              labels=c("BOTH PARENTS BORN IN US",
                                       "AT LEAST ONE PARENT BORN OUTSIDE US",
                                       "BOTH PARENTS BORN OUTSIDE US")),
         marital=factor(marital,levels=c(1,3:5),
                        labels=c("MARRIED OR SEPERATED",
                                 "WIDOWED",
                                 "DIVORCED",
                                 "NEVER MARRIED")),
         veteran=factor(veteran,levels=c(0:1),
                        labels=c("NOT A VETERAN",
                                 "VETERAN")),
         preg=factor(preg,levels=c(0:2),
                     labels=c("NOT PREGNANT IN LAST YEAR",
                              "PREGNANT AT DEATH",
                              "NOT PREGNANT AT DEATH, PREGNANT IN LAST YEAR")),
```

```
        dplace=factor(dplace,levels=c(1:8),
                      labels=c("HOSPITAL, INPATIENT",
                               "HOSPITAL, OUTPATIENT / ER",
                               "HOSPITAL, DOA",
                               "RESIDENCE",
                               "HOSPICE",
                               "NURSING HOME",
                               "ASSISTED LIVING FACILITY / REST HOME",
                               "OTHER")),
        travel=factor(travel,levels=c(0:1),
                      labels=c("DIED AND RESIDE IN SAME CITY",
                               "DIED AND RESIDE IN DIFFERENT CITIES")))

#### Class conversions ####
ind.f$dcity<-as.character(ind.f$dcity)
ind.f$ddad<-as.character(ind.f$ddad)
# ind$ddate<-as.character(ind$ddate)
ind.f$dfacilitynum<-as.character(ind.f$dfacilitynum)
ind.f$dnat<-as.character(ind.f$dnat)
ind.f$dstate<-as.character(ind.f$dstate)
ind.f$dzip<-as.character(ind.f$dzip)
ind.f$icd1<-as.character(ind.f$icd1)
ind.f$icd2<-as.character(ind.f$icd2)
ind.f$icd3<-as.character(ind.f$icd3)
ind.f$icd4<-as.character(ind.f$icd4)
ind.f$icd5<-as.character(ind.f$icd5)
ind.f$icd6<-as.character(ind.f$icd6)
ind.f$icd7<-as.character(ind.f$icd7)
ind.f$icd8<-as.character(ind.f$icd8)
ind.f$icd9<-as.character(ind.f$icd9)
ind.f$icd10<-as.character(ind.f$icd10)
ind.f$icd11<-as.character(ind.f$icd11)
ind.f$icd12<-as.character(ind.f$icd12)
ind.f$icd13<-as.character(ind.f$icd13)
ind.f$icd14<-as.character(ind.f$icd14)
ind.f$icd15<-as.character(ind.f$icd15)
ind.f$icd16<-as.character(ind.f$icd16)
ind.f$indust<-as.character(ind.f$indust)
ind.f$occup<-as.character(ind.f$occup)
ind.f$resadd<-as.character(ind.f$resadd)
ind.f$rescity<-as.character(ind.f$rescity)
ind.f$resnat<-as.character(ind.f$resnat)
ind.f$resstate<-as.character(ind.f$resstate)
ind.f$reszip<-as.character(ind.f$reszip)
ind.f$sfnum<-as.character(ind.f$sfnum)

head(ind.f)
```

```
##   batch  sfnum      ddate   male age               race          occup
## 1     2 635949 2014-10-01 FEMALE   7 NON-HISPANIC WHITE      Policeman
## 2     2 844076 2006-09-21   MALE   1       MULTI-RACIAL     Accountant
## 3     2 851223 2016-12-03   MALE  79 NON-HISPANIC BLACK          Pilot
## 4     2  50427 2013-02-13   MALE  13       MULTI-RACIAL        Teacher
```

```
## 5     1 341650 2005-02-11 FEMALE  96              OTHER Factory Worker
## 6     1 247560 2013-01-06   MALE  45              OTHER        Butcher
##               indust                                              edu
## 1 Emergency Services                                  SPECIAL EDUCATION
## 2            Banking                                  SPECIAL EDUCATION
## 3     Transportation                  BACHELOR'S / ASSOCIATE'S DEGREE
## 4           Academia HIGH SCHOOL / GED / CERTIFICATE / SOME COLLEGE
## 5      Manufacturing                               LESS THAN HIGHSCHOOL
## 6      Food/Beverage                                  SPECIAL EDUCATION
##                                immig                       pimmig
## 1               BORN AND LIVE IN US      BOTH PARENTS BORN IN US
## 2 BORN ELSEWHERE AND LIVE ELSEWHERE      BOTH PARENTS BORN IN US
## 3                    BORN ELSEWHERE      BOTH PARENTS BORN IN US
## 4               BORN AND LIVE IN US BOTH PARENTS BORN OUTSIDE US
## 5     BORN ELSEWHERE AND LIVE IN US      BOTH PARENTS BORN IN US
## 6                    BORN ELSEWHERE      BOTH PARENTS BORN IN US
##                marital       veteran
## 1             DIVORCED       VETERAN
## 2        NEVER MARRIED NOT A VETERAN
## 3 MARRIED OR SEPERATED       VETERAN
## 4              WIDOWED NOT A VETERAN
## 5             DIVORCED NOT A VETERAN
## 6        NEVER MARRIED NOT A VETERAN
##                                          preg         resadd rescity
## 1                           PREGNANT AT DEATH 1234 CIRCLE ST ANYTOWN
## 2                     NOT PREGNANT IN LAST YEAR 1234 CIRCLE ST ANYTOWN
## 3                     NOT PREGNANT IN LAST YEAR 1234 CIRCLE ST ANYTOWN
## 4 NOT PREGNANT AT DEATH, PREGNANT IN LAST YEAR 1234 CIRCLE ST ANYTOWN
## 5 NOT PREGNANT AT DEATH, PREGNANT IN LAST YEAR 1234 CIRCLE ST ANYTOWN
## 6 NOT PREGNANT AT DEATH, PREGNANT IN LAST YEAR 1234 CIRCLE ST ANYTOWN
##        resstate reszip        resnat                                dplace
## 1 MASSACHUSETTS  02367 UNITED STATES                  HOSPITAL, INPATIENT
## 2 MASSACHUSETTS  01012 UNITED STATES                              HOSPICE
## 3 MASSACHUSETTS  01368 UNITED STATES                         HOSPITAL, DOA
## 4 MASSACHUSETTS  02764 UNITED STATES ASSISTED LIVING FACILITY / REST HOME
## 5 MASSACHUSETTS  02770 UNITED STATES                                OTHER
## 6 MASSACHUSETTS  01368 UNITED STATES                            RESIDENCE
##   dfacilitynum           ddad   dcity        dstate  dzip          dnat
## 1       000000 1234 SQUARE ST ANYTOWN MASSACHUSETTS 01562 UNITED STATES
## 2       000000 1234 SQUARE ST ANYTOWN MASSACHUSETTS 02462 UNITED STATES
## 3       000000 1234 SQUARE ST ANYTOWN MASSACHUSETTS 02568 UNITED STATES
## 4       000000 1234 SQUARE ST ANYTOWN MASSACHUSETTS 02721 UNITED STATES
## 5       000000 1234 SQUARE ST ANYTOWN MASSACHUSETTS 01084 UNITED STATES
## 6       000000 1234 SQUARE ST ANYTOWN MASSACHUSETTS 01344 UNITED STATES
##                                travel    icd1    icd2    icd3    icd4
## 1        DIED AND RESIDE IN SAME CITY S80261D O3671X9 T582X2D S72422D
## 2 DIED AND RESIDE IN DIFFERENT CITIES S62652K   M3130 S062X9S   O4402
## 3        DIED AND RESIDE IN SAME CITY  H16143 T82513A V00898S   Y93I9
## 4        DIED AND RESIDE IN SAME CITY S62311G T440X2A S72046G S82851M
## 5 DIED AND RESIDE IN DIFFERENT CITIES T23059D S62607K S3790XA S76801S
## 6        DIED AND RESIDE IN SAME CITY S72413P S86009D S06340S  H25093
##      icd5    icd6    icd7    icd8    icd9   icd10   icd11   icd12   icd13
## 1 T41205S S72353C S72021G T23099D   O8629 T56892D   D5740 T20119A O365122
## 2 W3182XS    O662 S72114M V111XXA S66209A T24302D M84532K T7500XA S0030XA
```

```
## 3  M19022 V9331XA S43032D    M355 O3101X3 T4792XS   O2992 S72462H Y35031S
## 4  M435X8 S66109A S42353A  E09622  M88842   H4613 V833XXD S99911A S52346Q
## 5 S62367K Y36030D    N766 S62669D   F3177 S2329XA S6430XA   T3177 S72356R
## 6 T4592XA S21029D T433X6D T43225D  M12229   H8302 T2042XS T63444S  Z89011
##     icd14   icd15   icd16
## 1 T63821A    Z794   K0520
## 2 S0551XD S15291S  H04612
## 3 S72091G    K610 T493X6D
## 4 W16722S V419XXA S55291D
## 5 S92422A S61358A T83591A
## 6 T24231A T17918S S9401XS
```

Aggregate Data Set

```
# All possible combination of month, year, and zip
base<-data.frame(zip=rep(shp@data$ZCTA5CE10,(12*18)),
                 month=rep(c(rep(1,538),rep(2,538),rep(3,538),rep(4,538),
                         rep(5,538),rep(6,538),rep(7,538),rep(8,538),
                         rep(9,538),rep(10,538),rep(11,538),rep(12,538)),18),
                 year=c(rep(2000,538*12),rep(2001,538*12),rep(2002,538*12),
                        rep(2003,538*12),rep(2004,538*12),rep(2005,538*12),
                        rep(2006,538*12),rep(2007,538*12),rep(2008,538*12),
                        rep(2009,538*12),rep(2010,538*12),rep(2011,538*12),
                        rep(2012,538*12),rep(2013,538*12),rep(2014,538*12),
                        rep(2015,538*12),rep(2016,538*12),rep(2017,538*12)))
agMonth<-base%>%
  # join to aggregated counts
  left_join(ind%>%
              # Extract death year and month from date object
              mutate(dyear=year(as.Date(ddate)),
                     dmonth=month(as.Date(ddate)))%>%
              # Determine number of cases in each zip code in each month
              group_by(reszip,dyear,dmonth)%>%
              summarize(cases=n()),
            by=c("zip"="reszip","month"="dmonth","year"="dyear"))%>%
  # Turn NA to 0
  mutate(cases=map_dbl(.x=cases,.f=~if(is.na(.x)){return(0)}else{return(.x)}))

head(agMonth)
```

```
##     zip month year cases
## 1 02536     1 2000     0
## 2 02556     1 2000     0
## 3 02540     1 2000     0
## 4 02646     1 2000     0
## 5 01237     1 2000     0
## 6 01259     1 2000     0
```

Exploratory Data Analysis

Summary Tables

These tables give an overview of the data based on the type of data it is. Helpful during the data cleaning stage when deciding on possible class conversions.

```
#### Numeric Variables ####
ind.f%>%
  select(names(ind[map_lgl(ind.f,is.numeric)]))%>%
  gather(colnames(ind[map_lgl(ind.f,is.numeric)]),key=variable,value=value)%>%
  group_by(variable)%>%
  summarize(Mean=mean(value,na.rm=T),
  SD=sd(value,na.rm=T),
  R1=range(value,na.rm=T)[1],
  R2=range(value,na.rm=T)[2],
  UniqueValues=length(unique(value[!is.na(value)])),
  PropMissingness=sum(is.na(value))/length(value))%>%
  mutate(Range=paste0("[",R1,", ",R2,"]"),
         percent=paste0(round(PropMissingness*100,3),"%"))%>%
  select(Variable=variable,Mean,SD,Range,`Unique Values`=UniqueValues,Missingness=percent)%>%
  kable(booktabs=T,digits=3,
        caption="Summary of Quantitative Variables in Individual Data Set",align="c")%>%
  kable_styling(latex_options=c("HOLD_position","striped"),position="center")
```

Table 1: Summary of Quantitative Variables in Individual Data Set

Variable	Mean	SD	Range	Unique Values	Missingness
age	51.112	28.89	[0, 100]	101	0%

```
#### Character variables ####
ind.f%>%
  select(names(ind.f[map_lgl(ind.f,is.character)]))%>%
  gather(variable,value)%>%
  group_by(variable)%>%
  summarize(UniqueValues=length(unique(value[!is.na(value)])),
  PropMissingness=sum(is.na(value))/length(value))%>%
  mutate(percent=paste0(round(PropMissingness*100,3),"%"))%>%
  select(Variable=variable,`Unique Values`=UniqueValues,Missingness=percent)%>%
  kable(booktabs=T,digits=3,
        caption="Summary of Character Variables in Individual Data Set",align="c")%>%
  kable_styling(latex_options=c("HOLD_position","striped"),position="center")
```

Table 2: Summary of Character Variables in Individual Data Set

Variable	Unique Values	Missingness
dcity	1	0%
ddad	1	0%
dfacilitynum	1	0%
dnat	1	0%
dstate	1	0%
dzip	322	0%
icd1	493	0%
icd10	497	0%
icd11	491	0%
icd12	496	0%
icd13	494	0%
icd14	491	0%
icd15	498	0%
icd16	493	0%
icd2	495	0%
icd3	495	0%
icd4	495	0%
icd5	495	0%
icd6	496	0%
icd7	491	0%
icd8	491	0%
icd9	490	0%
indust	15	0%
occup	30	0%
resadd	1	0%
rescity	1	0%
resnat	1	0%
resstate	1	0%
reszip	326	0%
sfnum	500	0%

```
#### Factor variables ####
var<-names(ind.f)[map_lgl(ind.f,is.factor)]
fac<-data.frame()
for(i in 1:11){
  df<-as.data.frame(table(ind.f[,var[i]],useNA="always"))
  df$name<-var[i]
  fac<-bind_rows(fac,df)
}
fac%>%
  select(name,everything())%>%
  mutate(Freq=prettyNum(Freq,big.mark=","))%>%
  kable(booktabs=T,longtable=T,digits=3,caption="Summary of Categorical Variables in Individual Data Se
        col.names=c("Variable","Value","Frequency"))%>%
  kable_styling(latex_options=c("HOLD_position","repeat_header","striped"),position="center")%>%
  collapse_rows(columns=1,latex_hline="major",valign="middle")
```

Table 3: Summary of Categorical Variables in Individual Data Set

Variable	Value	Frequency
batch	1	241
	2	259
	NA	0
male	FEMALE	244
	MALE	256
	NA	0
race	NON-HISPANIC WHITE	48
	NON-HISPANIC BLACK	66
	HISPANIC / LATINO	75
	ASIAN	80
	NATIVE AMERICAN / AMERICAN INDIAN / ALASKA NATIVE	66
	MULTI-RACIAL	84
	OTHER	81
	NA	0
edu	LESS THAN HIGHSCHOOL	100
	HIGH SCHOOL / GED / CERTIFICATE / SOME COLLEGE	101
	BACHELOR'S / ASSOCIATE'S DEGREE	109
	MASTER'S DEGREE OR HIGHER	103
	SPECIAL EDUCATION	87
	NA	0
immig	BORN AND LIVE IN US	96
	BORN ELSEWHERE AND LIVE IN US	107
	BORN ELSEWHERE AND LIVE ELSEWHERE	108
	BORN IN US AND LIVE ELSEWHERE	96
	BORN ELSEWHERE	93
	NA	0
pimmig	BOTH PARENTS BORN IN US	173
	AT LEAST ONE PARENT BORN OUTSIDE US	158
	BOTH PARENTS BORN OUTSIDE US	169
	NA	0
marital	MARRIED OR SEPERATED	122
	WIDOWED	127
	DIVORCED	123
	NEVER MARRIED	128
	NA	0
veteran	NOT A VETERAN	247
	VETERAN	253
	NA	0
preg	NOT PREGNANT IN LAST YEAR	177
	PREGNANT AT DEATH	168
	NOT PREGNANT AT DEATH, PREGNANT IN LAST YEAR	155
	NA	0
	HOSPITAL, INPATIENT	68
	HOSPITAL, OUTPATIENT / ER	68
	HOSPITAL, DOA	69
	RESIDENCE	50

Table 3: Summary of Categorical Variables in Individual Data Set
(continued)

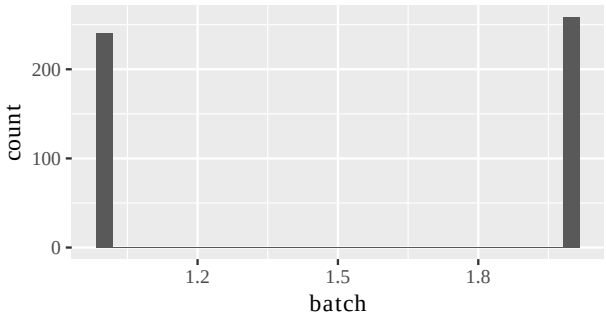
Variable	Value	Frequency
dplace	HOSPICE	66
	NURSING HOME	55
	ASSISTED LIVING FACILITY / REST HOME	63
	OTHER	61
	NA	0
	DIED AND RESIDE IN SAME CITY	239
travel	DIED AND RESIDE IN DIFFERENT CITIES	261
	NA	0

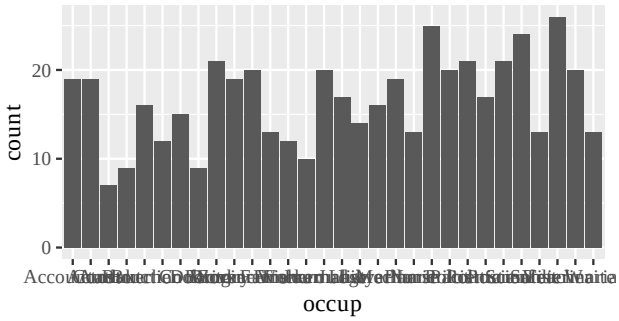
Univariate Graphics Loop

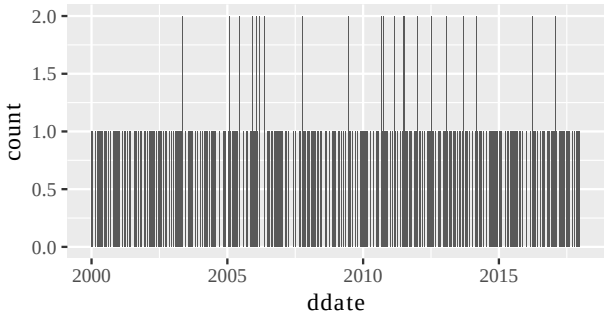
Plots all variables with appropriate graphical summaries. Used to find possible relationships for later investigation. Not all of these graphs are insightful, so an argument (`rmCol`) is available is specify variables for the function to ignore.

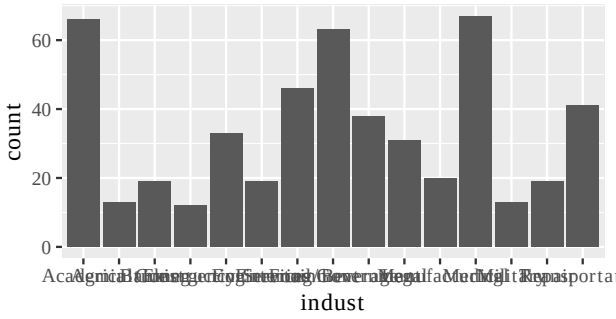
```
uni.plots<-function(dataset,rmCol=NULL){
  if(is.null(rmCol)){data<-dataset}
  else{data<-dataset[,-rmCol]}
  plots<-list()
  for (i in 1:length(data)){
    if (is.numeric(data[[i]])){
      plots[[i]]<- ggplot(data,aes_string(x=colnames(data[i])))+
                   geom_histogram()+
                   xlab(colnames(data[i]))+
                   ylab("count")+
                   theme(text=element_text(family="LM Roman 10"))
                   #axis.text.x=element_text(angle=45))
    } else {
      plots[[i]]<- ggplot(data,aes_string(x=colnames(data[i])))+
      geom_bar()+
      xlab(colnames(data[i]))+
      ylab("count")+
      theme(text=element_text(family="LM Roman 10"))
            #axis.text.x=element_text(angle=45))
    }
  }
  return(marrangeGrob(plots,nrow=5,ncol=2,top=textGrob("Univariate Plots",gp=gpar(fontsize=16,fontfamily
}

uni.plots(ind,c(2,15:17,19,21:24,26,28:length(ind)))
```

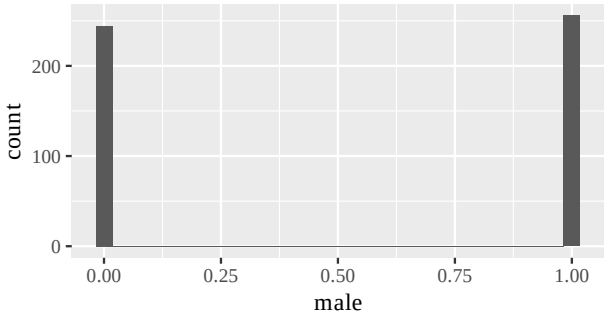
Univariate Plots

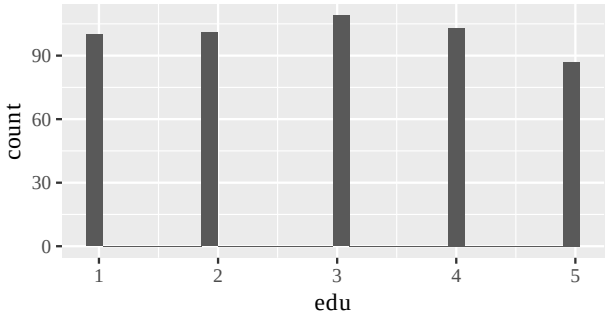


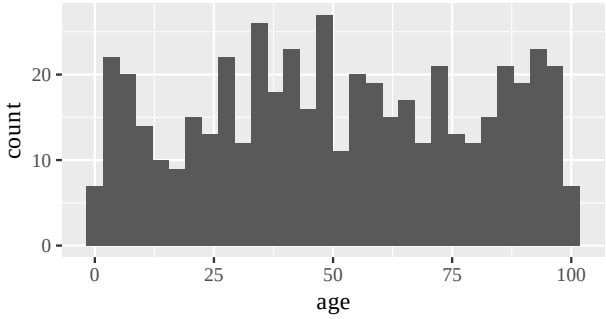


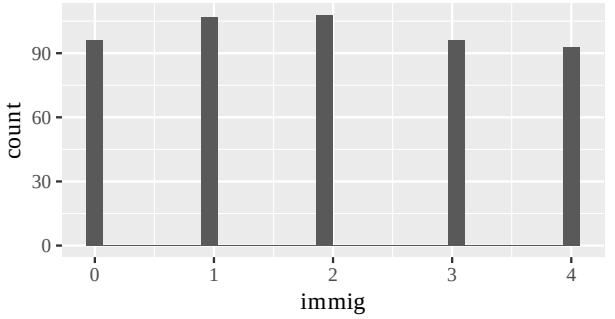


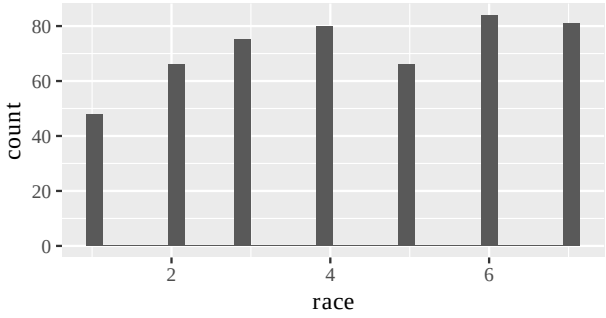


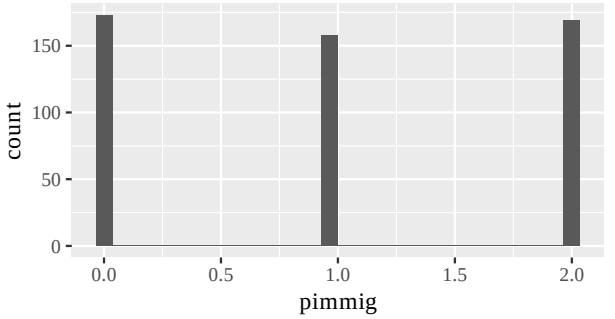




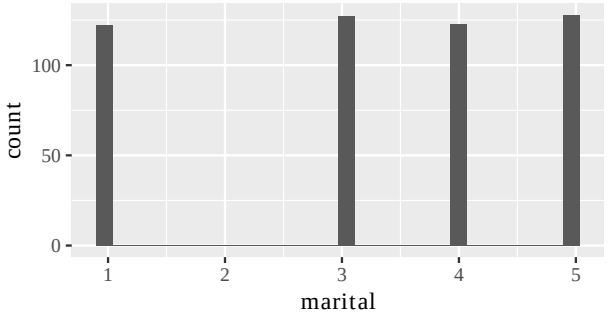


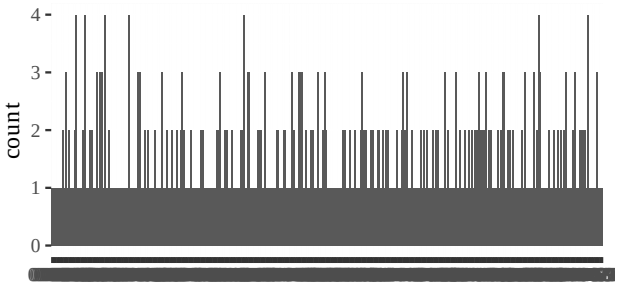


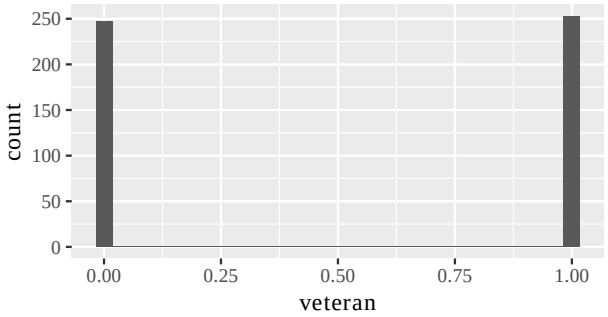


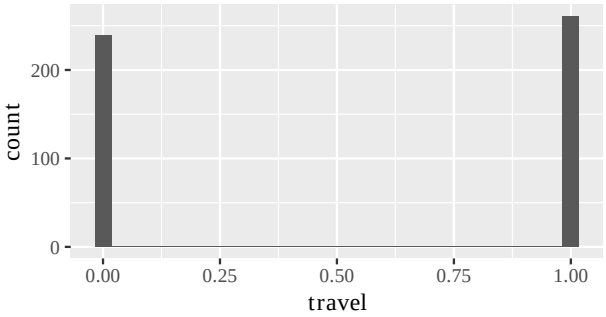


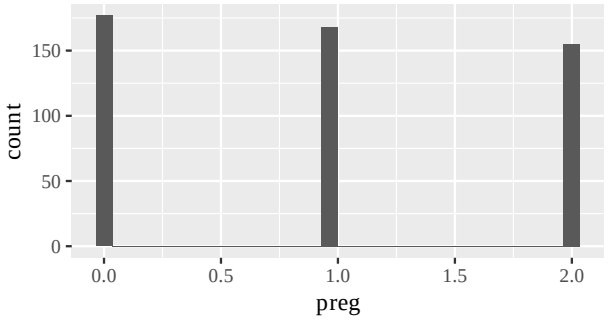
Univariate Plots

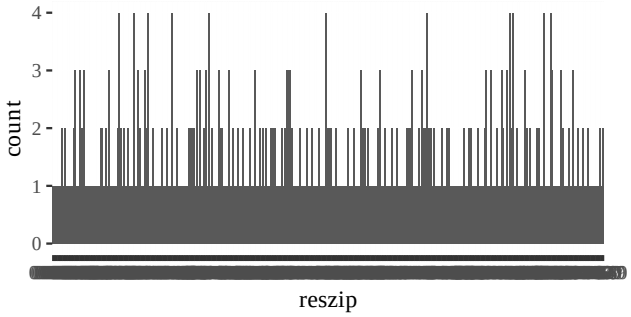


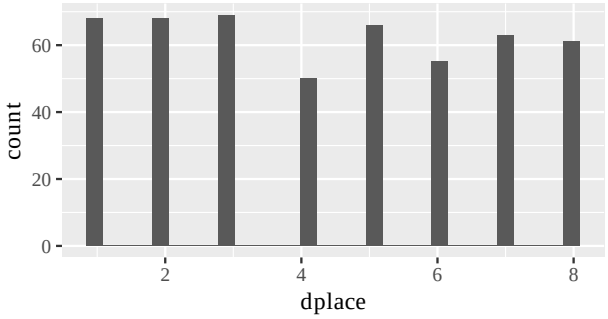












Cause of Death Tables

```
#### Joining in ICD10 descriptions ####
ind.f<-ind.f%>%
  left_join(icd10[,c(2,5)],by=c("icd1"="ICD10Code"))%>%
  rename(icd1.desc=LongDesc)%>%
  left_join(icd10[,c(2,5)],by=c("icd2"="ICD10Code"))%>%
  rename(icd2.desc=LongDesc)%>%
  left_join(icd10[,c(2,5)],by=c("icd3"="ICD10Code"))%>%
  rename(icd3.desc=LongDesc)%>%
  left_join(icd10[,c(2,5)],by=c("icd4"="ICD10Code"))%>%
  rename(icd4.desc=LongDesc)%>%
  left_join(icd10[,c(2,5)],by=c("icd5"="ICD10Code"))%>%
  rename(icd5.desc=LongDesc)%>%
  left_join(icd10[,c(2,5)],by=c("icd6"="ICD10Code"))%>%
  rename(icd6.desc=LongDesc)%>%
  left_join(icd10[,c(2,5)],by=c("icd7"="ICD10Code"))%>%
  rename(icd7.desc=LongDesc)%>%
  left_join(icd10[,c(2,5)],by=c("icd8"="ICD10Code"))%>%
  rename(icd8.desc=LongDesc)%>%
  left_join(icd10[,c(2,5)],by=c("icd9"="ICD10Code"))%>%
  rename(icd9.desc=LongDesc)%>%
  left_join(icd10[,c(2,5)],by=c("icd10"="ICD10Code"))%>%
  rename(icd10.desc=LongDesc)%>%
  left_join(icd10[,c(2,5)],by=c("icd11"="ICD10Code"))%>%
  rename(icd11.desc=LongDesc)%>%
  left_join(icd10[,c(2,5)],by=c("icd12"="ICD10Code"))%>%
  rename(icd12.desc=LongDesc)%>%
  left_join(icd10[,c(2,5)],by=c("icd13"="ICD10Code"))%>%
  rename(icd13.desc=LongDesc)%>%
  left_join(icd10[,c(2,5)],by=c("icd14"="ICD10Code"))%>%
  rename(icd14.desc=LongDesc)%>%
  left_join(icd10[,c(2,5)],by=c("icd15"="ICD10Code"))%>%
  rename(icd15.desc=LongDesc)%>%
  left_join(icd10[,c(2,5)],by=c("icd16"="ICD10Code"))%>%
  rename(icd16.desc=LongDesc)

#### Primary ####
```

```r
as.data.frame(table(ind.f$icd1.desc))%>%
  top_n(5,Freq)%>%
  kable(booktabs=T,digits=3,longtable=T,caption="Summary of Primary Causes of Death",align="c",
        col.names=c("Cause of Death","Frequency"))%>%
  kable_styling(latex_options=c("HOLD_position","striped","repeat_header"),position="center")%>%
  column_spec(1,width="8in")
```

Table 4: Summary of Primary Causes of Death

Cause of Death	Frequency
Nondisplaced fracture of coronoid process of left ulna, sequela	2
Ocular pain, unspecified eye	2
Other acute osteomyelitis, left tibia and fibula	2
Other specified disorders of amniotic fluid and membranes, third trimester, fetus 5	2
Parasitic endophthalmitis, unspecified, bilateral	2
Unspecified effects of high altitude, sequela	2
Unspecified fracture of shaft of unspecified radius, subsequent encounter for closed fracture with delayed healing	2

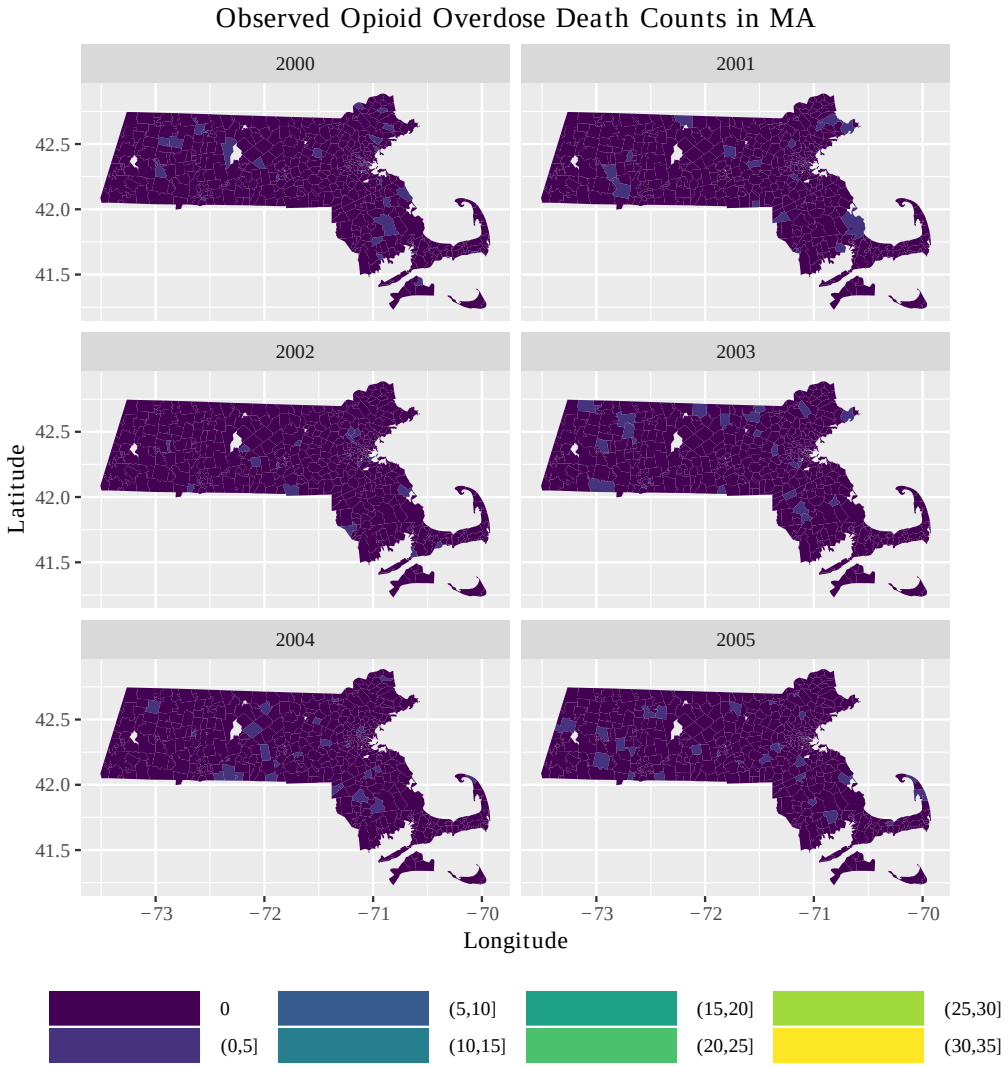

```r
#### Secondary ####
as.data.frame(table(ind.f$icd2.desc))%>%
  top_n(5,Freq)%>%
  kable(booktabs=T,digits=3,longtable=T,caption="Summary of Secondary Causes of Death",align="c",
        col.names=c("Cause of Death","Frequency"))%>%
  kable_styling(latex_options=c("HOLD_position","striped","repeat_header"),position="center")%>%
  column_spec(1,width="8in")
```

Table 5: Summary of Secondary Causes of Death

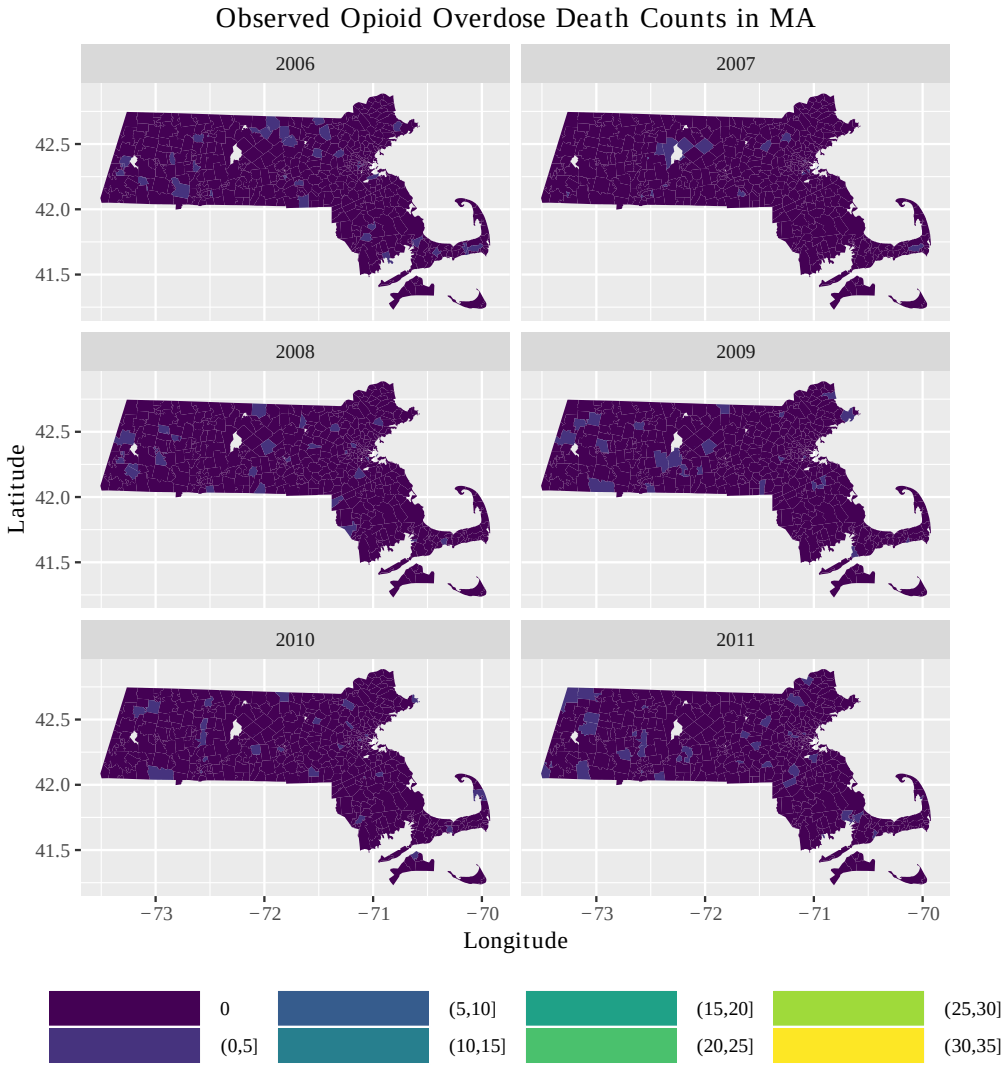
Cause of Death	Frequency
Animal-rider injured in transport accident with military vehicle, subsequent encounter	2
Burn of second degree of left upper arm, initial encounter	2
Fracture of alveolus of right mandible, subsequent encounter for fracture with nonunion	2
Nonrheumatic mitral (valve) prolapse	2
Pressure ulcer of right heel, unstageable	2

Mapping

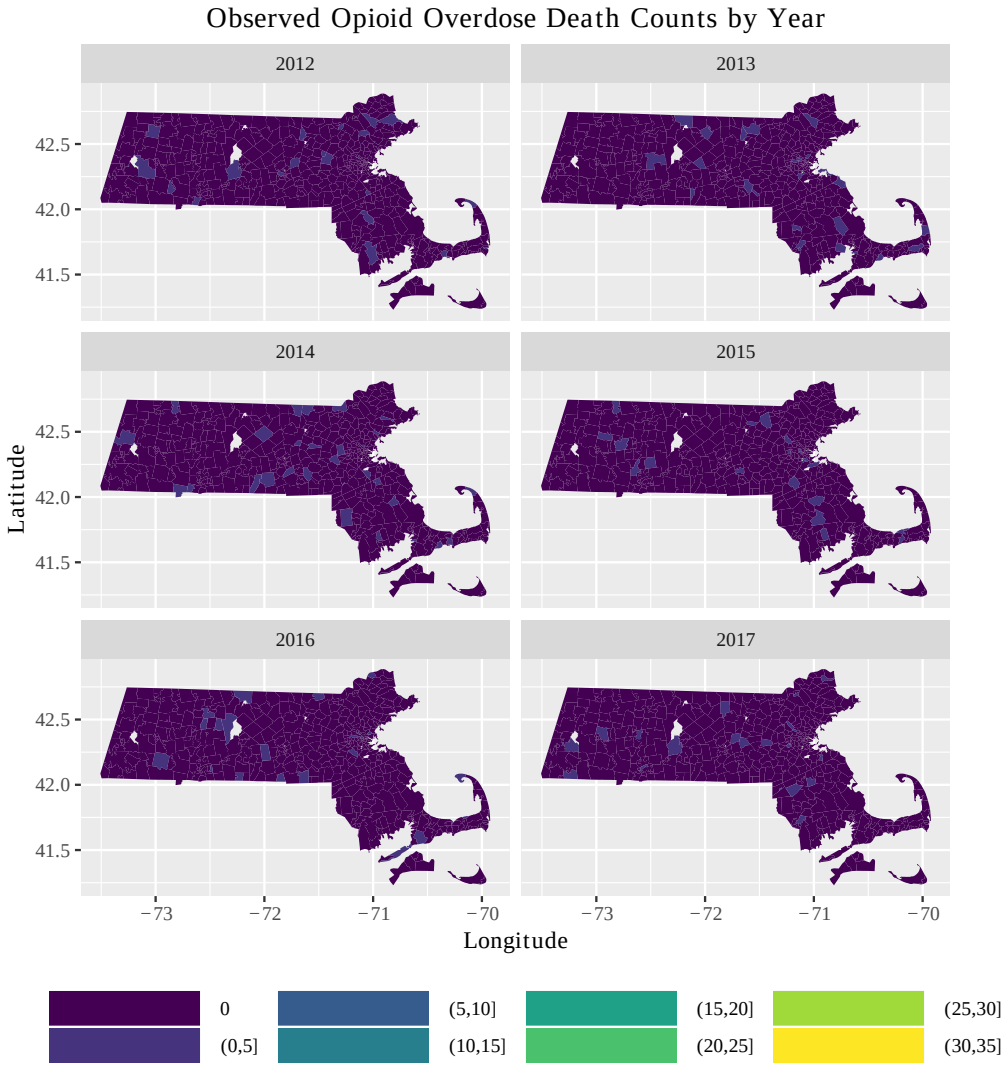
```
map<-fortify(shp,region="ZCTA5CE10")
map<- merge(map, agMonth%>%rename(id=zip)%>%group_by(id,year)%>%summarize(cases=sum(cases)), by="id", al
map<- map[order(map$order),]
# 2000-2005
ggplot()+
  geom_polygon(data=map[map$year<=2005,],
               aes(long,lat,group=group,fill=cut(cases,c(-1,0,5,10,15,20,25,30,35))),color=NA)+
  coord_fixed(1.2)+
  facet_wrap(~year,ncol=2)+
  scale_fill_viridis(discrete=T,drop=F,na.value="antiquewhite",
                     labels =c("0","(0,5]","(5,10]","(10,15]",
                               "(15,20]","(20,25]","(25,30]",
                               "(30,35]"))+
  labs(x="Longitude",y="Latitude",fill=NULL,title ="Observed Opioid Overdose Death Counts in MA")+
  theme(legend.position = "bottom",legend.key.width=unit(2.5,"cm"),
        legend.spacing.x = unit(.3, 'cm'),plot.title = element_text(hjust = 0.5),
        text=element_text(family="LM Roman 10"))
```




```
#2006-2011
ggplot()+
  geom_polygon(data=map[map$year<=2011&map$year>=2006,],
               aes(long,lat,group=group,fill=cut(cases,c(-1,0,5,10,15,20,25,30,35))),color=NA)+
  coord_fixed(1.2)+
  facet_wrap(~year,ncol=2)+
  scale_fill_viridis(discrete=T,drop=F,na.value="antiquewhite",
                     labels =c("0","(0,5]","(5,10]","(10,15]",
                               "(15,20]","(20,25]","(25,30]",
                               "(30,35]"))+
  labs(x="Longitude",y="Latitude",fill=NULL,title ="Observed Opioid Overdose Death Counts in MA")+
  theme(legend.position = "bottom",legend.key.width=unit(2.5,"cm"),
        legend.spacing.x = unit(.3, 'cm'),plot.title = element_text(hjust = 0.5),
        text=element_text(family="LM Roman 10"))
```




```
#2012-2017
ggplot()+
  geom_polygon(data=map[map$year<=2017&map$year>=2012,],
               aes(long,lat,group=group,fill=cut(cases,c(-1,0,5,10,15,20,25,30,35))),color=NA)+
  coord_fixed(1.2)+
  facet_wrap(~year,ncol=2)+
  scale_fill_viridis(discrete=T,drop=F,na.value="antiquewhite",
                     labels =c("0","(0,5]","(5,10]","(10,15]",
                               "(15,20]","(20,25]","(25,30]",
                               "(30,35]"))+
  labs(x="Longitude",y="Latitude",fill=NULL,title ="Observed Opioid Overdose Death Counts by Year")+
  theme(legend.position = "bottom",legend.key.width=unit(2.5,"cm"),
        legend.spacing.x = unit(.3, 'cm'),plot.title = element_text(hjust = 0.5),
        text=element_text(family="LM Roman 10"))
```




```
map<-fortify(shp,region="ZCTA5CE10")
map<- merge(map,
            agMonth%>%
              rename(id=zip)%>%
              mutate(month=month(month,label=T,abbr=F))%>%
              group_by(id,month)%>%
              summarize(cases=sum(cases)), by="id", all.x = TRUE)
map<- map[order(map$order),]
# Jan-Jul
ggplot()+
  geom_polygon(data=map[map$month=="January"|
                        map$month=="February"|
                        map$month=="March"|
                        map$month=="April"|
                        map$month=="May"|
                        map$month=="June",],
               aes(long,lat,group=group,fill=cut(cases,c(-1,0,5,10,15,20,25,30,35))),color=NA)+
  coord_fixed(1.2)+
```

```
  facet_wrap(~month,ncol=2)+
  scale_fill_viridis(discrete=T,drop=F,na.value="antiquewhite",
                     labels =c("0","(0,5]","(5,10]","(10,15]",
                               "(15,20]","(20,25]","(25,30]",
                               "(30,35]"))+
  labs(x="Longitude",y="Latitude",fill=NULL,title ="Observed Opioid Overdose Death Counts in MA")+
  theme(legend.position = "bottom",legend.key.width=unit(2.5,"cm"),
        legend.spacing.x = unit(.3, 'cm'),plot.title = element_text(hjust = 0.5),
        text=element_text(family="LM Roman 10"))
```


Observed Opioid Overdose Death Counts in MA
January
February
March
April
May
June
Latitude
42.5
42.0
41.5
−73
−72
−71
−70
Longitude
0
(0,5]
(5,10]
(10,15]
(15,20]
(20,25]
(25,30]
(30,35]

```
# Aug-Dec
ggplot()+
  geom_polygon(data=map[map$month=="July"|
                        map$month=="August"|
                        map$month=="September"|
                        map$month=="October"|
                        map$month=="November"|
                        map$month=="December",],
               aes(long,lat,group=group,fill=cut(cases,c(-1,0,5,10,15,20,25,30,35))),color=NA)+
  coord_fixed(1.2)+
  facet_wrap(~month,ncol=2)+
  scale_fill_viridis(discrete=T,drop=F,na.value="antiquewhite",
                     labels =c("0","(0,5]","(5,10]","(10,15]",
                               "(15,20]","(20,25]","(25,30]",
                               "(30,35]"))+
  labs(x="Longitude",y="Latitude",fill=NULL,title ="Observed Opioid Overdose Death Counts in MA")+
  theme(legend.position = "bottom",legend.key.width=unit(2.5,"cm"),
        legend.spacing.x = unit(.3, 'cm'),plot.title = element_text(hjust = 0.5),
        text=element_text(family="LM Roman 10"))
```


Observed Opioid Overdose Death Counts in MA
July
August
September
October
November
December
Latitude
42.5
42.0
41.5
−73
−72
−71
−70
Longitude
0
(0,5]
(5,10]
(10,15]
(15,20]
(20,25]
(25,30]
(30,35]