SEACAR Continuous Water Quality Analysis: SW Region for pH

Last compiled on 01 June, 2022

Contents

Important Notes

All scripts and outputs can be found on the SEACAR GitHub repository:

https://github.com/FloridaSEACAR/SEACAR_Panzik

Note: The top 2% of data is excluded when computing mean and standard deviations in plotting sections solely for the purpose of getting y-axis scales. The exclusion of the top 2% is not used in any statistics that are exported.

Libraries

Loads libraries used in the script. The inclusion of `scipen` option limits how frequently R defaults to scientific notation.

```
library(knitr)
library(data.table)
library(dplyr)
library(lubridate)
library(ggplot2)
library(ggpubr)
library(scales)
library(EnvStats)
library(tidyr)
options(scipen = 999)
opts_chunk$set(warning=FALSE, message=FALSE)
```

File Import

Imports file that is determined in the WC_Continuous_parameter_ReportCompile.R script.

The command `fread` is used because of its improved speed while handling large data files. Only columns that are used by the script are imported from the file, and are designated in the `select` input.

The script then gets the name of the parameter as it appears in the data file and units of the parameter.

```
data <- fread(file_in, sep = "|", header = TRUE, stringsAsFactors = FALSE,
              select = c("ManagedAreaName", "ProgramID", "ProgramName",
                         "ProgramLocationID", "SampleDate", "Year", "Month",
                         "RelativeDepth", "ActivityType", "ParameterName",
                         "ResultValue", "ParameterUnits", "ValueQualifier",
                         "SEACAR_QAQCFlagCode", "Include"),
              na.strings = "")
parameter <- unique(data$ParameterName)
unit <- unique(data$ParameterUnits)
```

Data Filtering

Most data filtering is performed on export from the database, and is indicated by the `Include` variable. `Include` values of 1 indicate the data should be used for analysis, values of 0 indicate the data should not be used for analysis. Documentation on the database filtering is provided here: SEACAR Documentation-Analysis Filters and Calculations.docx

The filtering that is performed by the script at this point removes rows that are missing values for `ResultValue` and `RelativeDepth`, and removes any activity type that has "Blank" in the description. Data passes the filtering the process if it is has an `Include` value of 1.

The script then gets the units of the parameter, sets the `SampleDate` as a date object, and creates various scales of the date to be used by plotting functions.

Because the continuous data is extensive and most measurements are taken every 15 minutes, a daily average is determined and used based on grouping `ManagedAreaName`, `ProgramID`, `ProgramName`, `ProgramLocationID`, and `SampleDate`. The new `ResultValue` is the mean of all values on that date from that specific monitoring location. Sets the `SampleDate` as a date object, and creates various scales of the date to be used by plotting functions.

Creates a variable for each `MonitoringID` which is defined as a unique combination of `ManagedAreaName`, `ProgramID`, `ProgramAreaName`, and `ProgramLocationID`.

After the initial filtering, a second filter variable is created to determine whether enough time is represented in the managed area, which is that each managed area has 5 year or more of unique year entries for observation that pass the initial filter. If data passes the first set of filtering criteria and the time criteria, they are used in the analysis.

```
data$Include <- as.logical(data$Include)
data <- data[data$Include==TRUE,]
data <- data[!is.na(data$ResultValue),]
data <- data[!is.na(data$RelativeDepth),]
data <- data[!grep("Blank", data$ActivityType),]

if(param_name == "Water_Temperature"){
   data <- data[data$ResultValue>=-5,]
} else{
   data <- data[data$ResultValue>=0,]
}



data <- data %>%
   group_by(ManagedAreaName, ProgramID, ProgramName, ProgramLocationID,
            SampleDate) %>%
   summarise(Year = unique(Year), Month = unique(Month),
             RelativeDepth = unique(RelativeDepth),
             ResultValue = mean(ResultValue), Include = unique(Include))

data <- merge.data.frame(MA_All[,c("AreaID", "ManagedAreaName")],
                         data, by = "ManagedAreaName", all=TRUE)

data$SampleDate <- as.Date(data$SampleDate)
data$YearMonth <- paste0(data$Month, "-", data$Year)
data$YearMonthDec <- data$Year + ((data$Month-0.5) / 12)
data$DecDate <- decimal_date(data$SampleDate)

data <- data %>%
    group_by(ManagedAreaName, ProgramID, ProgramName, ProgramLocationID) %>%
    mutate(MonitoringID = cur_group_id())
# data <- data %>%
#    mutate(MonitoringID = group_indices(., ManagedAreaName, ProgramID,
#                                        ProgramName, ProgramLocationID))

Mon_Summ <- data %>%
   group_by(MonitoringID, AreaID, ManagedAreaName, ProgramID, ProgramName,
            ProgramLocationID) %>%
   summarize(ParameterName=parameter,
             RelativeDepth=unique(RelativeDepth),
             N_Data=length(ResultValue[Include==TRUE & !is.na(ResultValue)]),
             N_Years=length(unique(Year[Include==TRUE & !is.na(Year)])),
             EarliestYear=min(Year[Include==TRUE]),
             LatestYear=max(Year[Include==TRUE]),
             SufficientData=ifelse(N_Data>0 & N_Years>=10, TRUE, FALSE))
#
# Mon_Years <- data[data$Include == TRUE, ] %>%
#    group_by(MonitoringID) %>%
```

```
#    summarize(AreaID = unique(AreaID),
#              ManagedAreaName = unique(ManagedAreaName),
#              ProgramID = unique(ProgramID),
#              ProgramName = unique(ProgramName),
#              ProgramLocationID = unique(ProgramLocationID),
#              ParameterName = parameter,
#              RelativeDepth = unique(RelativeDepth),
#              Y = length(unique(Year)))
Mon_Summ <- as.data.table(Mon_Summ[order(Mon_Summ$MonitoringID), ])

data <- merge.data.frame(data, Mon_Summ[,c("MonitoringID", "SufficientData")],
                         by = "MonitoringID")
# data$Exclude_MonitoringID <- is.element(data$MonitoringID,
#                                         Mon_Years$MonitoringID[
#                                           Mon_Years$Enough_Time == FALSE])
data$Use_In_Analysis <- ifelse(data$Include == TRUE &
                                 data$SufficientData == TRUE, TRUE, FALSE)

Mon_IDs <- unique(data$MonitoringID[data$Use_In_Analysis == TRUE])
Mon_IDs <- Mon_IDs[order(Mon_IDs)]
n <- length(Mon_IDs)
```

Monitoring Location Statistics

Gets summary statistics for each monitoring location. Excluded monitoring locations are not included into whether the data should be used or not. Uses piping from dplyr package to feed into subsequent steps. The following steps are performed:

1. Take the `data` variable and only include rows that have a `Use_In_Analysis` value of TRUE
2. Group data that have the same `ManagedAreaName`, `ProgramID`, `ProgramName`, `ProgramLocationID`, `Year`, and `Month`.
   - Second summary statistics consider the monitoring location grouping and `Year`.
   - Third summary statistics consider the monitoring location grouping and `Month`.
3. For each group, provide the following information: Earliest Sample Date (EarliestSampleDate), Latest Sample Date (LastSampleDate), Number of Entries (N), Lowest Value (Min), Largest Value (Max), Median, Mean, Standard Deviation, and a list of all Program IDs included in these measurements.
4. Sort the data in ascending (A to Z and 0 to 9) order based on `ManagedAreaName`, `ProgramID`, `ProgramName`, `ProgramLocationID`, `Year`, and `Month` in that order.
5. Write summary stats to a pipe-delimited .txt file in the output directory

```
Mon_YM_Stats <- data[data$Use_In_Analysis == TRUE, ] %>%
   group_by(AreaID, ManagedAreaName, ProgramID, ProgramName, ProgramLocationID,
            Year, Month) %>%
   summarize(ParameterName = parameter,
             RelativeDepth = unique(RelativeDepth),
             EarliestSampleDate = min(SampleDate),
             LastSampleDate = max(SampleDate), N = length(ResultValue),
             Min = min(ResultValue), Max = max(ResultValue),
             Median = median(ResultValue), Mean = mean(ResultValue),
             StandardDeviation = sd(ResultValue))
```

```
Mon_YM_Stats <- as.data.table(Mon_YM_Stats[order(Mon_YM_Stats$ManagedAreaName,
                                                Mon_YM_Stats$ProgramID,
                                                Mon_YM_Stats$ProgramName,
                                                Mon_YM_Stats$ProgramLocationID,
                                                Mon_YM_Stats$Year,
                                                Mon_YM_Stats$Month), ])
fwrite(Mon_YM_Stats, paste0(out_dir,"/", param_name, "_", region,
                            "_MonitoringLoc_YearMonth_Stats.txt"), sep = "|")

Mon_Y_Stats <- data[data$Use_In_Analysis == TRUE, ] %>%
   group_by(AreaID, ManagedAreaName, ProgramID, ProgramName, ProgramLocationID,
            Year) %>%
   summarize(ParameterName = parameter,
             RelativeDepth = unique(RelativeDepth),
             EarliestSampleDate = min(SampleDate),
             LastSampleDate = max(SampleDate), N = length(ResultValue),
             Min = min(ResultValue), Max = max(ResultValue),
             Median = median(ResultValue), Mean = mean(ResultValue),
             StandardDeviation = sd(ResultValue))
Mon_Y_Stats <- as.data.table(Mon_Y_Stats[order(Mon_Y_Stats$ManagedAreaName,
                                               Mon_Y_Stats$ProgramID,
                                               Mon_Y_Stats$ProgramName,
                                               Mon_Y_Stats$ProgramLocationID,
                                               Mon_Y_Stats$Year), ])
fwrite(Mon_Y_Stats, paste0(out_dir,"/", param_name, "_", region,
                           "_MonitoringLoc_Year_Stats.txt"), sep = "|")

Mon_M_Stats <- data[data$Use_In_Analysis == TRUE, ] %>%
   group_by(AreaID, ManagedAreaName, ProgramID, ProgramName, ProgramLocationID,
            Month) %>%
   summarize(ParameterName = parameter,
             RelativeDepth = unique(RelativeDepth),
             EarliestSampleDate = min(SampleDate),
             LastSampleDate = max(SampleDate), N = length(ResultValue),
             Min = min(ResultValue), Max = max(ResultValue),
             Median = median(ResultValue), Mean = mean(ResultValue),
             StandardDeviation = sd(ResultValue))
Mon_M_Stats <- as.data.table(Mon_M_Stats[order(Mon_M_Stats$ManagedAreaName,
                                               Mon_M_Stats$ProgramID,
                                               Mon_M_Stats$ProgramName,
                                               Mon_M_Stats$ProgramLocationID,
                                               Mon_M_Stats$Month), ])

fwrite(Mon_M_Stats, paste0(out_dir,"/", param_name, "_", region,
                           "_MonitoringLoc_Month_Stats.txt"), sep = "|")
```

Seasonal Kendall Tau Analysis

Gets seasonal Kendall Tau statistics using the `kendallSeasonalTrendTest` from the `EnvStats` package. The `Trend` parameter is determined from a user-defined function based on the median, Senn slope, and p values from the data. Analysis modified from that performed at The Water Atlas: https://sarasota.wateratlas.usf.edu/water-quality-trends/#analysis-overview

The following steps are performed:

1. Define the trend function.
2. Take the `data` variable and only include rows that have a `Use_In_Analysis` value of `TRUE`
3. Group data that have the same `ManagedAreaName`, `ProgramID`, `ProgramName`, and `ProgramLocationID`.
4. For each group, provides the following information: Earliest Sample Date (EarliestSampleDate), Latest Sample Date (LastSampleDate), Number of Entries (N), Lowest Value (Min), Largest Value (Max), Median, Mean, Standard Deviation,
5. For each group, a temporary variable is created to run the `kendallSeasonalTrendTest` function using the `Year` values for year, and `Month` as the seasonal qualifier, and Trend.
    - An independent.obs value of `TRUE` indicates that the data should be treated as not being serially auto-correlated. An independent.obs value of `FALSE` indicates that it is treated as being serially auto-correlated, but also requires one observation per season per year for the full time of observation.
    - tau, Senn Slope (SennSlope), Senn Intercept (SennIntercept), and p are extracted from the model results.
6. The two stats tables are merged based on similar groups, and then Trend is determined from the user-defined function.
7. Write summary stats to a pipe-delimited .txt file in the output directory
    - Click this text to open Git directory with output files
8. Add the Monitoring IDS to `KT.Stats` for easier use while plotting.

```
tauSeasonal <- function(data, independent, stats.median, stats.minYear,
                        stats.maxYear) {
   tau <- NULL
   tryCatch({ken <- kendallSeasonalTrendTest(
      y = data$ResultValue,
      season = data$Month,
      year = data$Year,
      independent.obs = independent)

   tau <- ken$estimate[1]
   p <- ken$p.value[2]
   slope <- ken$estimate[2]
   intercept <- ken$estimate[3]
   trend <- trend_calculator(slope, stats.median, p)
   rm(ken)
   }, warning = function(w) {
      print(w)
   }, error = function(e) {
      print(e)
   }, finally = {
      if (!exists("tau")) {
         tau <- NA
      }
      if (!exists("p")) {
         p <- NA
```

```
      }
      if (!exists("slope")) {
         slope <- NA
      }
      if (!exists("intercept")) {
         intercept <- NA
      }
      if (!exists("trend")) {
         trend <- NA
      }
   })
   KT <-c(unique(data$MonitoringID),
          stats.median,
          independent,
          tau,
          p,
          slope,
          intercept,
          trend)
   return(KT)
}
runStats <- function(data) {
   data$Index <- as.Date(data$SampleDate) # , "%Y-%m-%d")
   data$ResultValue <- as.numeric(data$ResultValue)
   # Calculate basic stats
   stats.median <- median(data$ResultValue, na.rm = TRUE)
   stats.minYear <- min(data$Year, na.rm = TRUE)
   stats.maxYear <- max(data$Year, na.rm = TRUE)
   # Calculate Kendall Tau and Slope stats, then update appropriate columns and table
   KT <- tauSeasonal(data, TRUE, stats.median,
                     stats.minYear, stats.maxYear)
   if (is.null(KT[8])) {
      KT <- tauSeasonal(data, FALSE, stats.median,
                        stats.minYear, stats.maxYear)
   }
   if (is.null(KT.Stats) == TRUE) {
      KT.Stats <- KT
   } else{
      KT.Stats <- rbind(KT.Stats, KT)
   }
   return(KT.Stats)
}
trend_calculator <- function(slope, median_value, p) {
   trend <-
      if (p < .05 & abs(slope) > abs(median_value) / 10.) {
         if (slope > 0) {
            2
         }
         else {
            -2
         }
      }
   else if (p < .05 & abs(slope) < abs(median_value) / 10.) {
```

```
      if (slope > 0) {
         1
      }
      else {
         -1
      }
   }
   else
      0
   return(trend)
}
KT.Stats <- NULL
# Loop that goes through each managed area.
# List of managed areas stored in MA_Years$ManagedAreaName
c_names <- c("MonitoringID", "Median", "Independent", "tau", "p",
             "SennSlope", "SennIntercept", "Trend")
if(n==0){
   KT.Stats <- data.frame(matrix(ncol=length(c_names),
                                 nrow=nrow(Mon_Summ)))
   colnames(KT.Stats) <- c_names
   KT.Stats[, c("MonitoringID")] <- Mon_Summ[, c("MonitoringID")]
} else{
   for (i in 1:n) {
      x <- nrow(data[data$Use_In_Analysis == TRUE &
                        data$MonitoringID == Mon_IDs[i], ])
      if (x>0) {
         KT.Stats <- runStats(data[data$Use_In_Analysis == TRUE &
                                      data$MonitoringID == Mon_IDs[i], ])
      }
   }
   KT.Stats <- as.data.frame(KT.Stats)

   if(dim(KT.Stats)[2]==1){
      KT.Stats <- as.data.frame(t(KT.Stats))
   }
   colnames(KT.Stats) <- c_names
   rownames(KT.Stats) <- seq(1:nrow(KT.Stats))
   KT.Stats$tau <- round(as.numeric(KT.Stats$tau), digits=4)
   KT.Stats$p <- round(as.numeric(KT.Stats$p), digits=4)
   KT.Stats$SennSlope <- as.numeric(KT.Stats$SennSlope)
   KT.Stats$SennIntercept <- as.numeric(KT.Stats$SennIntercept)
   KT.Stats$Trend <- as.integer(KT.Stats$Trend)
}

KT.Stats <-  merge.data.frame(Mon_Summ, KT.Stats,
                              by=c("MonitoringID"), all=TRUE)

KT.Stats <- as.data.table(KT.Stats[order(KT.Stats$MonitoringID), ])

KT.Stats$MonitoringID <- NULL
fwrite(KT.Stats, paste0(out_dir,"/", param_name, "_", region,
                           "_KendallTau_Stats.txt"), sep = "|")
```

```
KT.Stats$MonitoringID <- Mon_Summ$MonitoringID
data <- data[!is.na(data$ResultValue),]
```

Appendix I: Dataset Summary Box Plots

Box plots are created by using the entire data set and excludes any data that has been previously filtered out. The scripts that create plots follow this format

1. Use the data set that only has `Use_In_Analysis` of `TRUE`
2. Set what values are to be used for the x-axis, y-axis, and the variable that should determine groups for the box plots
3. Set the plot type as a box plot with the size of the outlier points
4. Create the title, x-axis, y-axis, and color fill labels
5. Set the y and x limits
6. Make the axis labels bold
7. Plot the arrangement as a set of panels

This set of box plots are grouped by year.

```
plot_theme <- theme_bw() + theme(text=element_text(family="Segoe UI"),
                                 title=element_text(face="bold"),
                                 plot.title=element_text(hjust=0.5,
                                                         size=14,
                                                         color="#314963"),
                                 plot.subtitle=element_text(hjust=0.5,
                                                            size=10,
                                                            color="#314963"),
                                 axis.text.x=element_text(face="bold"),
                                 axis.text.y=element_text(face="bold"))

min_RV <- min(data$ResultValue[data$Include == TRUE])
mn_RV <- mean(data$ResultValue[data$Include == TRUE &
                                 data$ResultValue <
                                 quantile(data$ResultValue, 0.98)])
sd_RV <- sd(data$ResultValue[data$Include == TRUE &
                               data$ResultValue <
                               quantile(data$ResultValue, 0.98)])
y_scale <- mn_RV + 4 * sd_RV

p1 <- ggplot(data = data[data$Include == TRUE, ],
             aes(x = Year, y = ResultValue, group = Year)) +
   geom_boxplot(color="#333333", fill="#cccccc", outlier.shape=21,
                outlier.size=3, outlier.color="#333333",
                outlier.fill="#cccccc", outlier.alpha=0.75) +
   labs(subtitle = "Autoscale", x = "Year",
        y = paste0("Values (", unit, ")")) +
   plot_theme

p2 <- ggplot(data = data[data$Include == TRUE, ],
             aes(x = Year, y = ResultValue, group = Year)) +
   geom_boxplot(color="#333333", fill="#cccccc", outlier.shape=21,
```

```
                outlier.size=3, outlier.color="#333333",
                outlier.fill="#cccccc", outlier.alpha=0.75) +
   labs(subtitle = "Scaled to 4x Standard Deviation", x = "Year",
        y = paste0("Values (", unit, ")")) +
   ylim(0, y_scale) +
   plot_theme

p3 <- ggplot(data = data[data$Include == TRUE, ],
             aes(x = as.integer(Year), y = ResultValue, group = Year)) +
   geom_boxplot(color="#333333", fill="#cccccc", outlier.shape=21,
                outlier.size=3, outlier.color="#333333",
                outlier.fill="#cccccc", outlier.alpha=0.75) +
   labs(subtitle = "Scaled to 4x Standard Deviation, Last 10 Years",
        x = "Year", y = paste0("Values (", unit, ")")) +
   ylim(0, y_scale) +
   scale_x_continuous(limits = c(max(data$Year) - 10.5, max(data$Year)+0.5),
                      breaks = seq(max(data$Year) - 10, max(data$Year), 2)) +
   plot_theme

set <- ggarrange(p1, p2, p3, ncol = 1)

p0 <- ggplot() + labs(title = "Summary Box Plots for Entire Data",
                      subtitle = "By Year") + plot_theme +
   theme(panel.border = element_blank(), panel.grid.major = element_blank(),
         panel.grid.minor = element_blank(), axis.line = element_blank())

Yset <- ggarrange(p0, set, ncol=1, heights = c(0.07, 1))
```

This set of box plots are grouped by year and month with the color being related to the month.

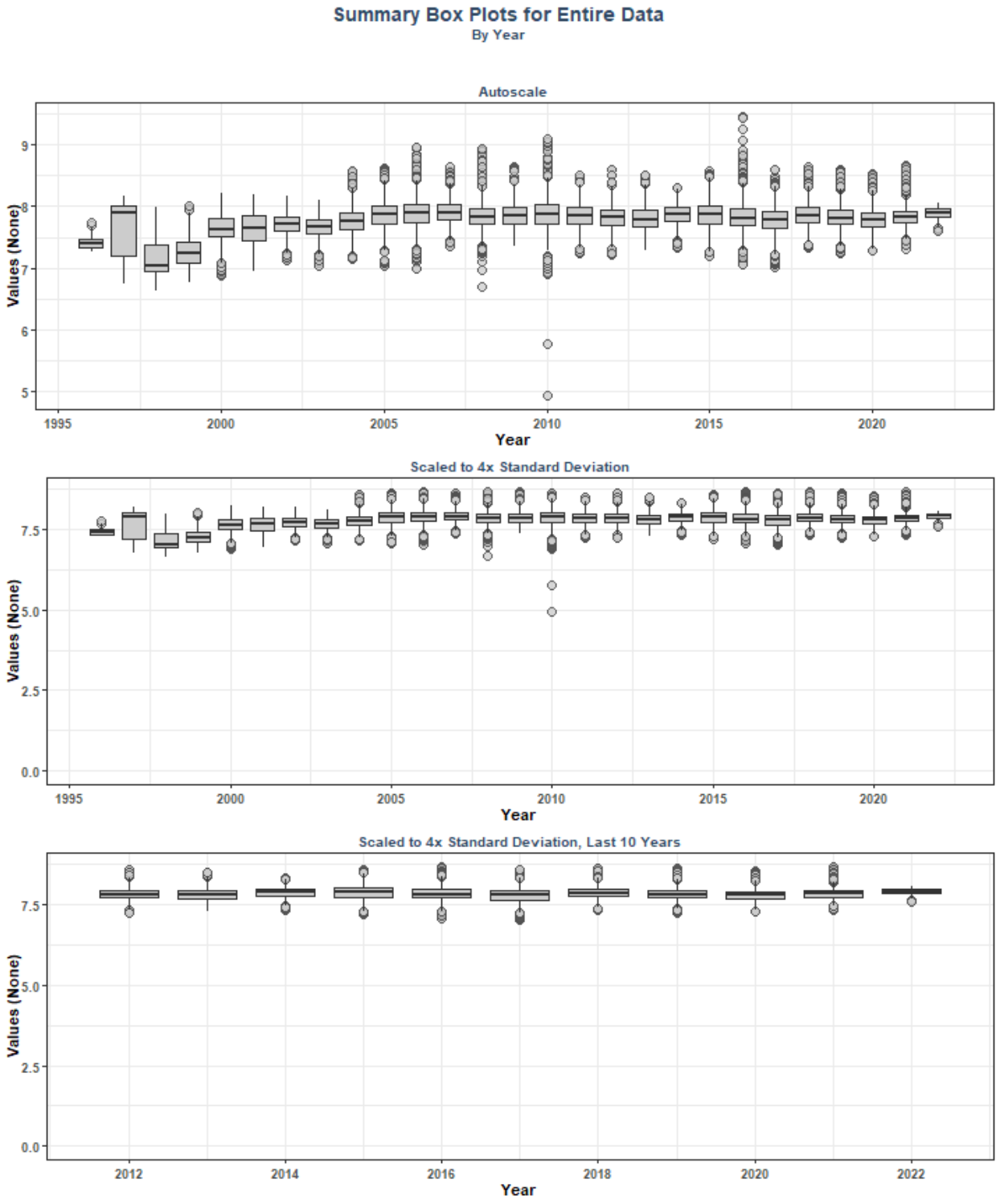
```
p1 <- ggplot(data = data[data$Include == TRUE, ],
             aes(x = YearMonthDec, y = ResultValue,
                 group = YearMonth, color = as.factor(Month))) +
   geom_boxplot(fill="#cccccc", outlier.size=1.5, outlier.alpha=0.75) +
   labs(subtitle = "Autoscale", x = "Year",
        y = paste0("Values (", unit, ")"), color="Month") +
   plot_theme +
   theme(legend.position = "top", legend.box = "horizontal") +
   guides(color = guide_legend(nrow = 1))

p2 <- ggplot(data = data[data$Include == TRUE, ],
             aes(x = YearMonthDec, y = ResultValue,
                 group = YearMonth, color = as.factor(Month))) +
   geom_boxplot(fill="#cccccc", outlier.size=1.5, outlier.alpha=0.75) +
   labs(subtitle = "Scaled to 5x Standard Deviation",
        x = "Year", y = paste0("Values (", unit, ")")) +
   ylim(0, y_scale) +
   plot_theme +
   theme(legend.position = "none")

p3 <- ggplot(data = data[data$Include == TRUE, ],
             aes(x = YearMonthDec, y = ResultValue,
                 group = YearMonth, color = as.factor(Month))) +
```

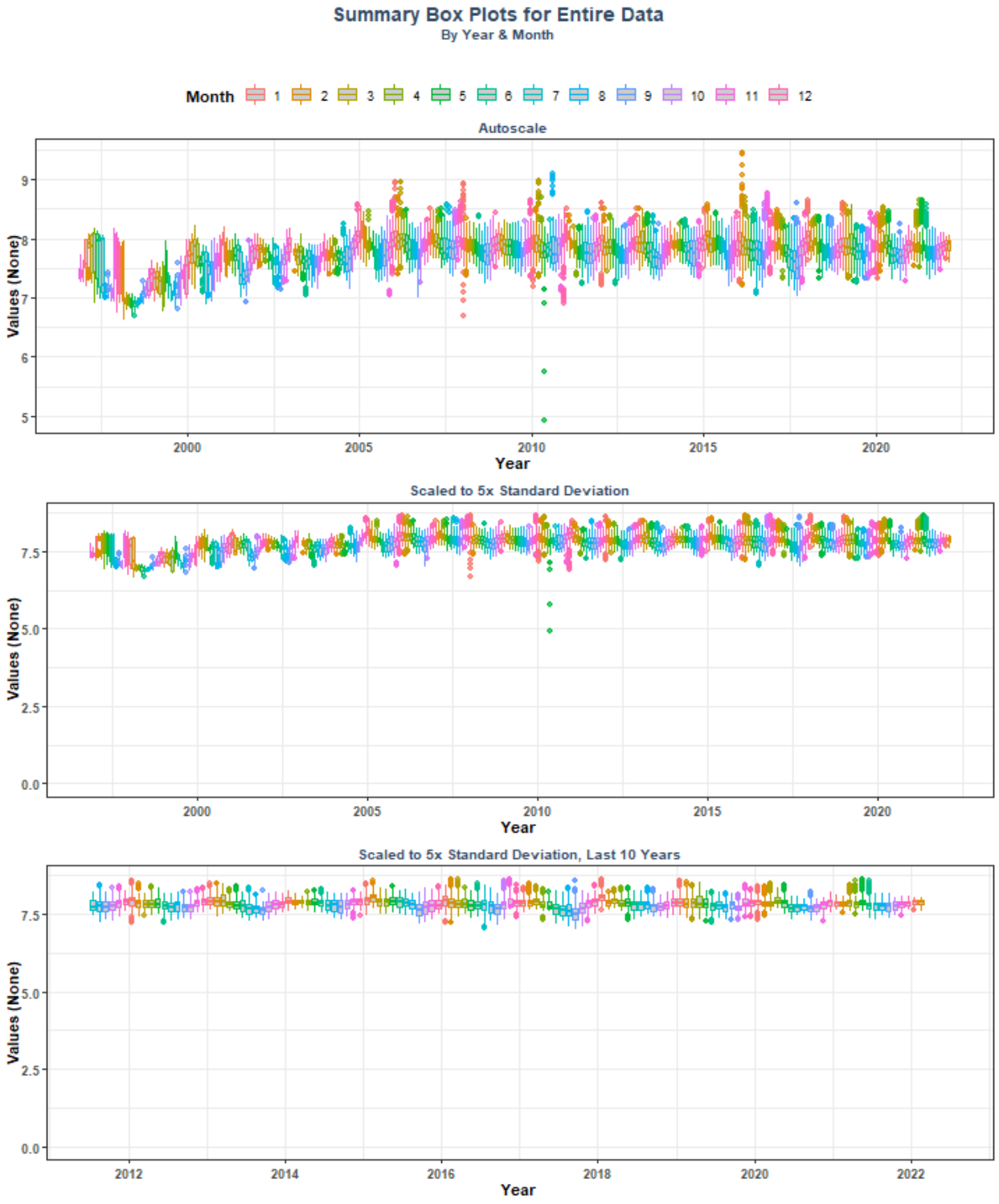
```
   geom_boxplot(fill="#cccccc", outlier.size=1.5, outlier.alpha=0.75) +
   labs(subtitle = "Scaled to 5x Standard Deviation, Last 10 Years",
        x = "Year", y = paste0("Values (", unit, ")")) +
   ylim(0, y_scale) +
   scale_x_continuous(limits = c(max(data$Year) - 10.5, max(data$Year)+0.5),
                      breaks = seq(max(data$Year) - 10, max(data$Year), 2)) +
   plot_theme +
   theme(legend.position = "none")
leg <- get_legend(p1)
set <- ggarrange(leg, p1 + theme(legend.position = "none"), p2, p3, ncol = 1,
                 heights = c(0.1, 1, 1, 1))

p0 <- ggplot() + labs(title = "Summary Box Plots for Entire Data",
                      subtitle = "By Year & Month") + plot_theme +
   theme(panel.border = element_blank(), panel.grid.major = element_blank(),
         panel.grid.minor = element_blank(), axis.line = element_blank())

YMset <- ggarrange(p0, set, ncol=1, heights = c(0.07, 1))
```

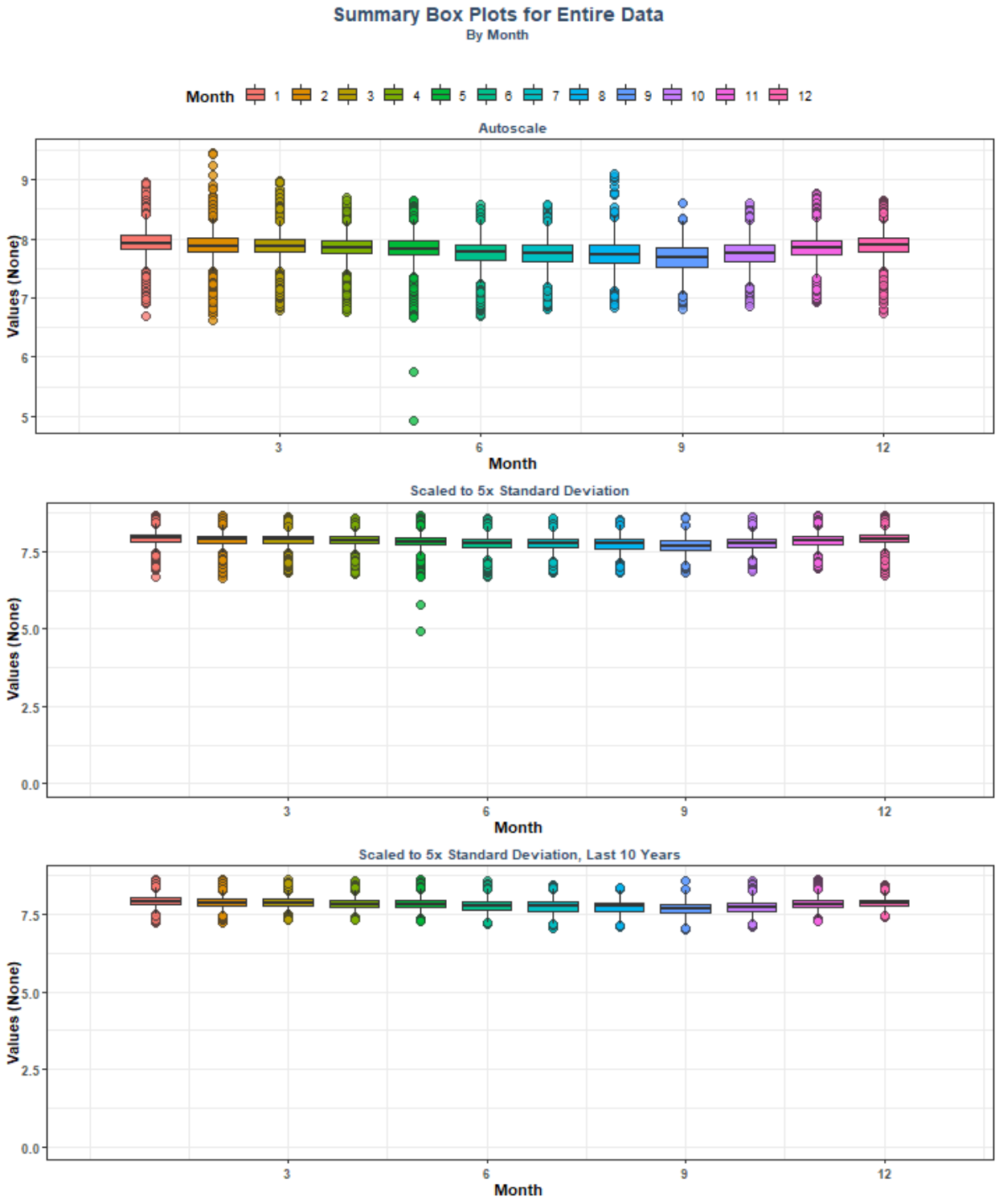
The following box plots are grouped by month with fill color being related to the month. This is designed to view potential seasonal trends.

```
p1 <- ggplot(data = data[data$Include == TRUE, ],
             aes(x = Month, y = ResultValue,
                 group = Month, fill = as.factor(Month))) +
   geom_boxplot(color="#333333", outlier.shape=21, outlier.size=3,
                outlier.color="#333333", outlier.alpha=0.75) +
   labs(subtitle = "Autoscale", x = "Month",
        y = paste0("Values (", unit, ")"), fill="Month") +
   scale_x_continuous(limits = c(0, 13), breaks = seq(3, 12, 3)) +
   plot_theme +
   theme(legend.position = "top", legend.box = "horizontal") +
   guides(fill = guide_legend(nrow = 1))

p2 <- ggplot(data = data[data$Include == TRUE, ],
             aes(x = Month, y = ResultValue,
                 group = Month, fill = as.factor(Month))) +
   geom_boxplot(color="#333333", outlier.shape=21, outlier.size=3,
                outlier.color="#333333", outlier.alpha=0.75) +
   labs(subtitle = "Scaled to 5x Standard Deviation",
        x = "Month", y = paste0("Values (", unit, ")")) +
   ylim(0, y_scale) +
   scale_x_continuous(limits = c(0, 13), breaks = seq(3, 12, 3)) +
   plot_theme +
   theme(legend.position = "none")

p3 <- ggplot(data = data[data$Include == TRUE &
                           data$Year >= max(data$Year) - 10, ],
             aes(x = Month, y = ResultValue,
                 group = Month, fill = as.factor(Month))) +
   geom_boxplot(color="#333333", outlier.shape=21, outlier.size=3,
                outlier.color="#333333", outlier.alpha=0.75) +
   labs(subtitle = "Scaled to 5x Standard Deviation, Last 10 Years",
```

```
       x = "Month", y = paste0("Values (", unit, ")")) +
   ylim(0, y_scale) +
   scale_x_continuous(limits = c(0, 13), breaks = seq(3, 12, 3)) +
   plot_theme +
   theme(legend.position = "none")
leg <- get_legend(p1)
set <- ggarrange(leg, p1 + theme(legend.position = "none"), p2, p3, ncol = 1,
                 heights = c(0.1, 1, 1, 1))

p0 <- ggplot() + labs(title = "Summary Box Plots for Entire Data",
                      subtitle = "By Month") + plot_theme +
   theme(panel.border = element_blank(), panel.grid.major = element_blank(),
         panel.grid.minor = element_blank(), axis.line = element_blank())

Mset <- ggarrange(p0, set, ncol=1, heights = c(0.07, 1))
```


Summary Box Plots for Entire Data
By Year
Autoscale
Values (None)
Year
Scaled to 4x Standard Deviation
Values (None)
Year
Scaled to 4x Standard Deviation, Last 10 Years
Values (None)
Year


Summary Box Plots for Entire Data
By Year & Month
Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (None)
Year
Scaled to 5x Standard Deviation
Values (None)
Year
Scaled to 5x Standard Deviation, Last 10 Years
Values (None)
Year

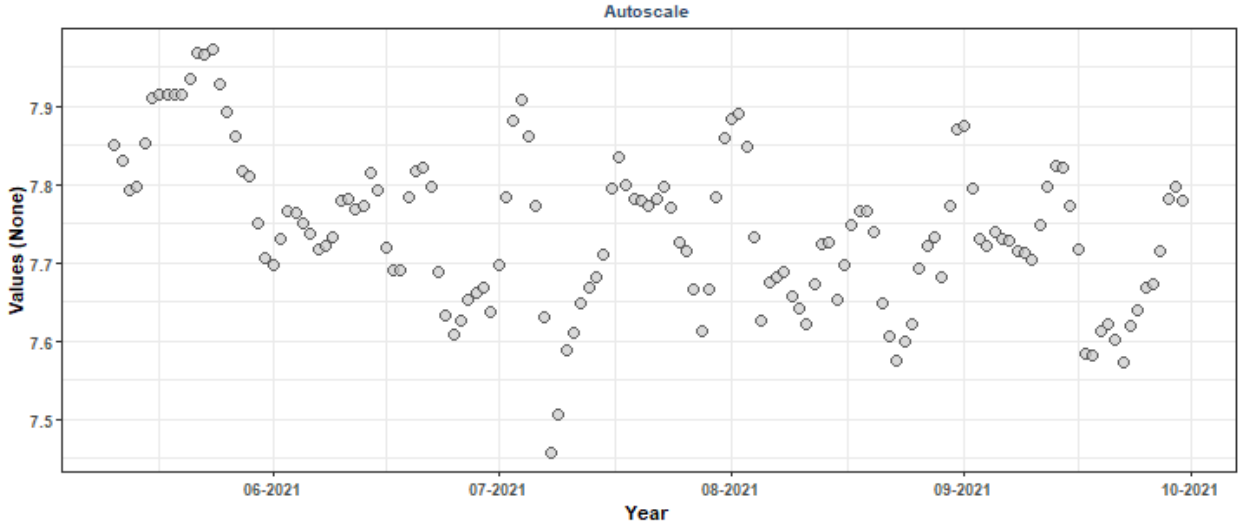


Appendix II: Excluded Monitoring Locations

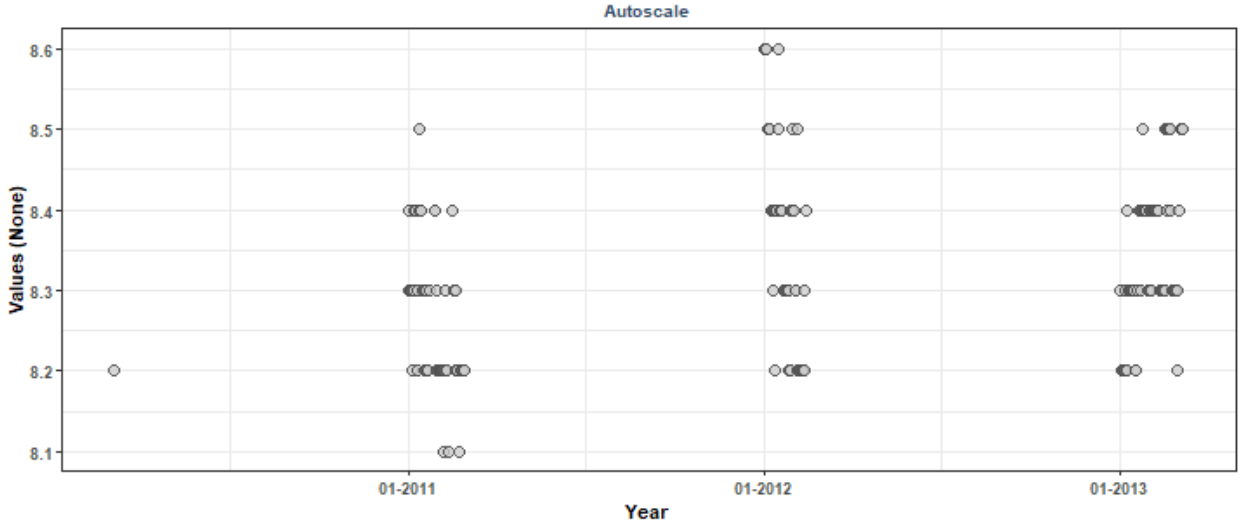
Scatter plots of data values are created for monitoring locationss that have fewer than 5 separate years of data entries.

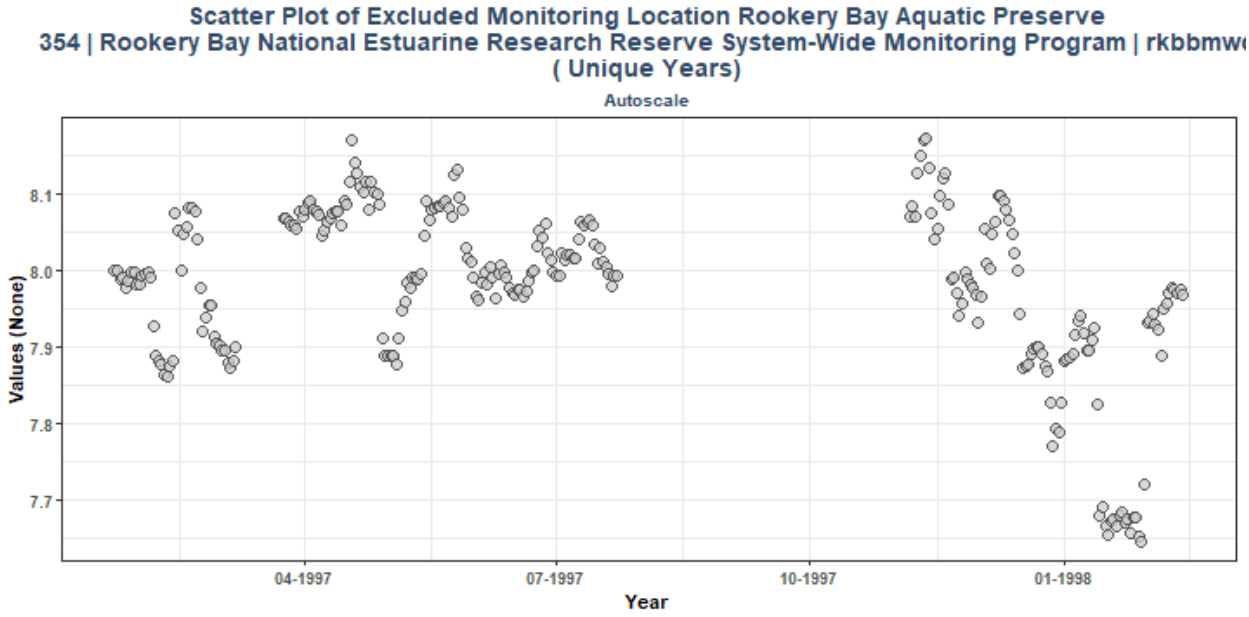
```
Mon_Exclude <- Mon_Summ[Mon_Summ$N_Years<5 & Mon_Summ$N_Years>0,]
Mon_Exclude <- Mon_Exclude[order(Mon_Exclude$MonitoringID),]
z=nrow(Mon_Exclude)

if(z==0){
   print("There are no monitoring locations that qualify.")
} else {
   for(i in 1:z){
      MA_name <- unique(data$ManagedAreaName[
         data$MonitoringID==Mon_Exclude$MonitoringID[i]])
      Mon_name <- paste(unique(data$ProgramID[
         data$MonitoringID==Mon_Exclude$MonitoringID[i]]),
         unique(data$ProgramName[
            data$MonitoringID==Mon_Exclude$MonitoringID[i]]),
         unique(data$ProgramLocationID[
            data$MonitoringID==Mon_Exclude$MonitoringID[i]]),
         sep = " | ")

      p1<-ggplot(data=data[data$MonitoringID==Mon_Exclude$MonitoringID[i]&
                              data$Include == TRUE, ],
                 aes(x = SampleDate, y = ResultValue)) +
         geom_point(shape=21, size=3, color="#333333", fill="#cccccc",
                    alpha=0.75) +
         labs(title=
                 paste0("Scatter Plot of Excluded Monitoring Location ",
                        MA_name, "\n", Mon_name, "\n(", Mon_Exclude$Y[i],
                        " Unique Years)"),
              subtitle="Autoscale", x = "Year",
              y = paste0("Values (", unit, ")")) +
         plot_theme +
         scale_x_date(labels = date_format("%m-%Y"))
      print(p1)
   }
}
```

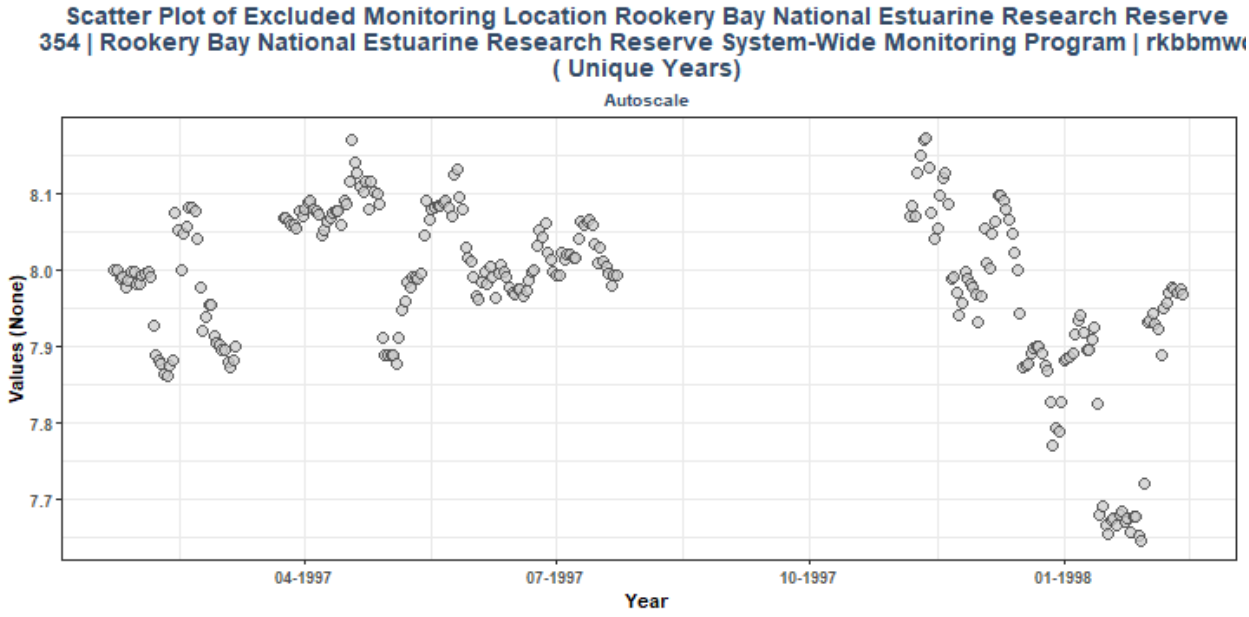
Scatter Plot of Excluded Monitoring Location Estero Bay Aquatic Preserve
474 | Estero Bay Aquatic Preserve Continuous Water Quality Monitoring | EB04
(Unique Years)

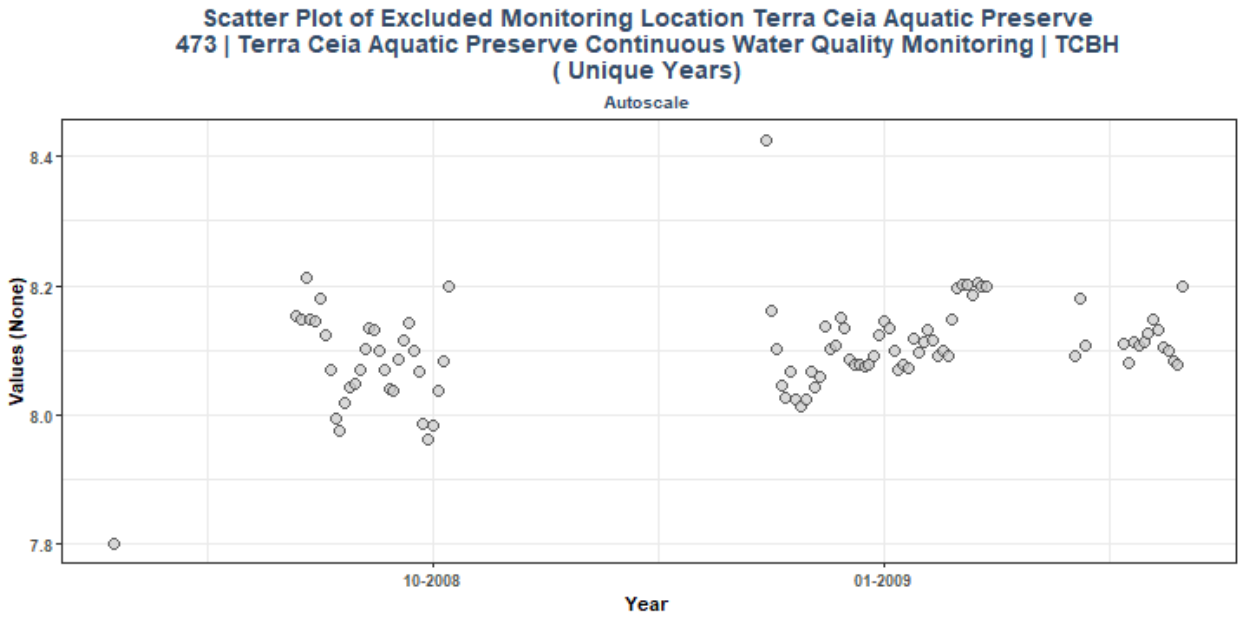


Scatter Plot of Excluded Monitoring Location Pine Island Sound Aquatic Preserve
7 | National Water Information System | 02293249
(Unique Years)




Scatter Plot of Excluded Monitoring Location Rookery Bay Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbbmw
(Unique Years)
Autoscale
Values (None)
8.1
8.0
7.9
7.8
7.7
04-1997
07-1997
10-1997
01-1998
Year


Scatter Plot of Excluded Monitoring Location Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbbmw
(Unique Years)
Autoscale
Values (None)
8.1
8.0
7.9
7.8
7.7
04-1997
07-1997
10-1997
01-1998
Year



Appendix III: Monitoring Location Trendlines

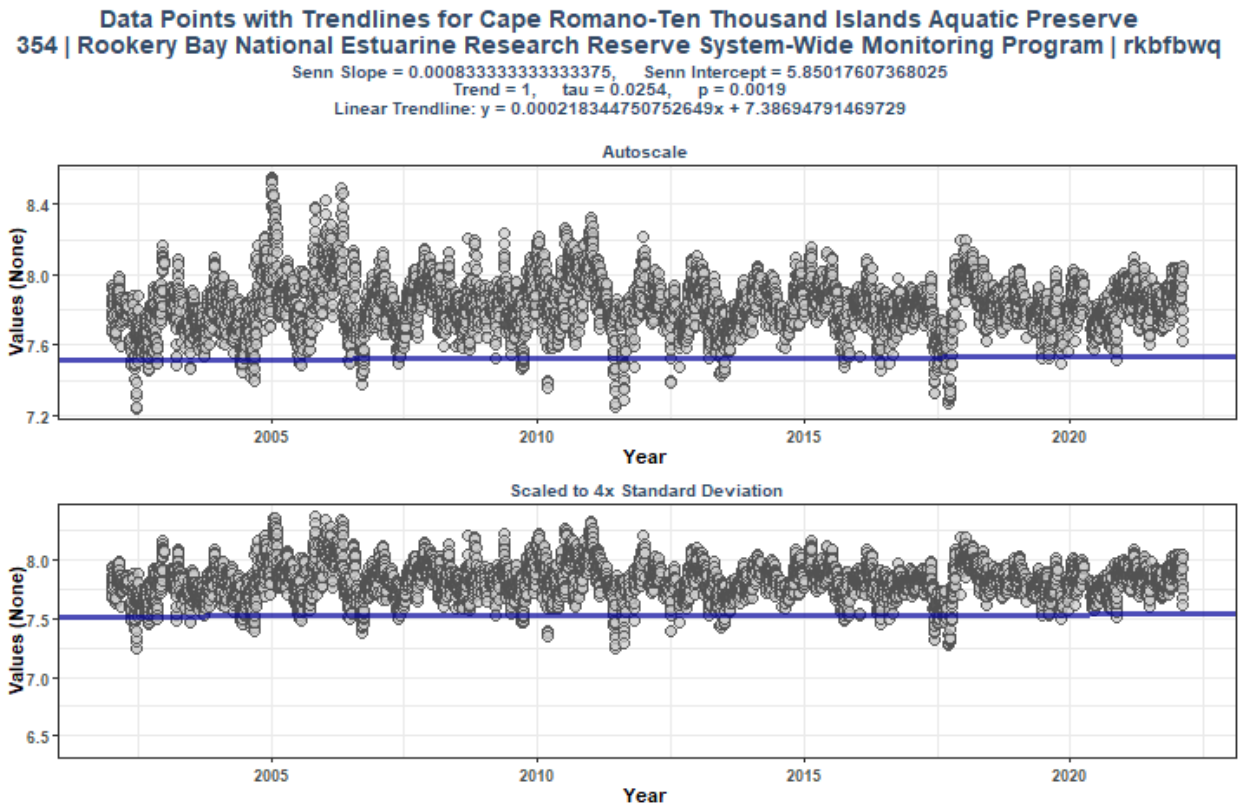
The plots created in this section are designed to show the general trend of the data. Data is taken and grouped by `MonitoringID`. The trendlines on the plots are created using the Senn slope and intercept from the seasonal Kendall Tau analysis. The scripts that create plots follow this format

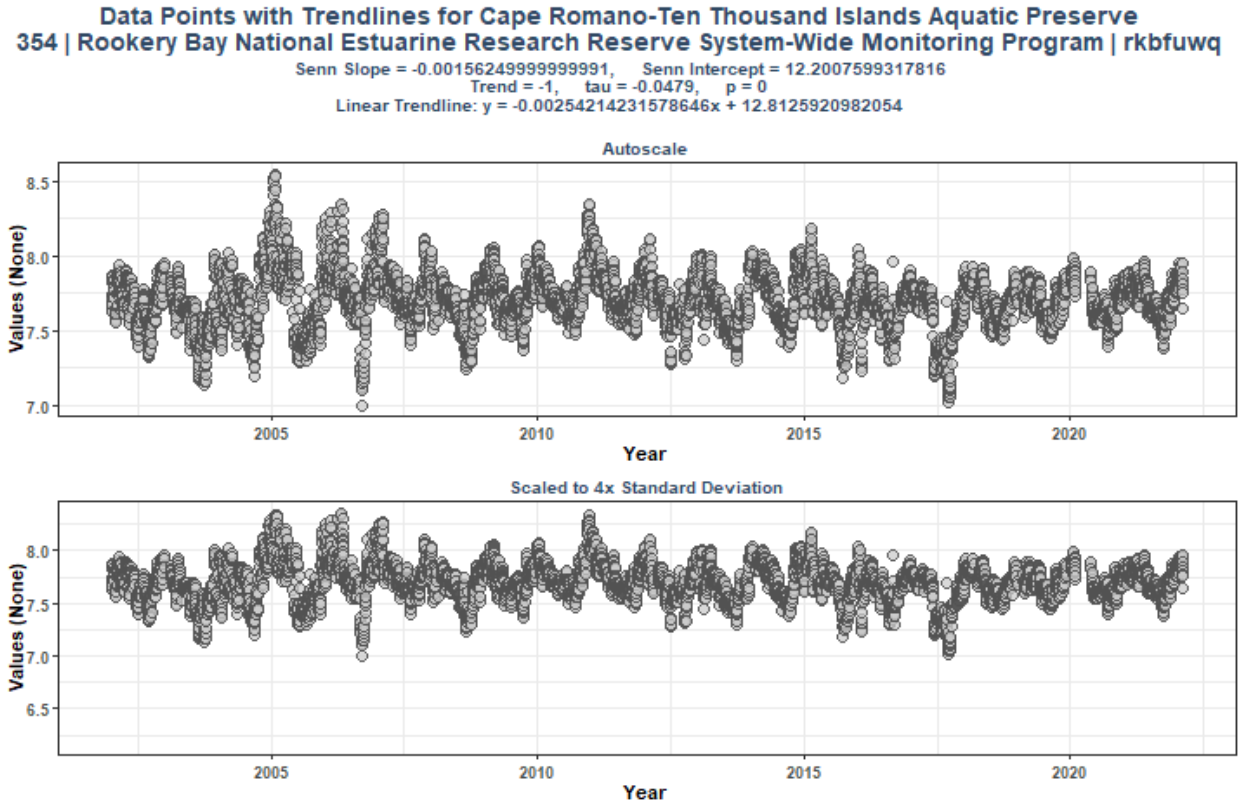
1. Use the data set that only has `Use_In_Analysis` of `TRUE` for the desired monitoring location
2. Determine the earliest and latest year of the data to create x-axis scale and intervals
3. Determine the minimum, mean, and standard deviation for the data to be used for y-axis scales
    - Excludes the top 2% of values to reduce the impact of extreme outliers on the y-axis scale
4. Set what values are to be used for the x-axis, y-axis, and the variable that should determine groups for the plots
5. Set the plot type as a point plot with the size of the points
6. Add the linear trend
7. Create the title, x-axis, y-axis, and color fill labels
8. Set the y and x limits
9. Make the axis labels bold
10. Plot the arrangement as a set of panels

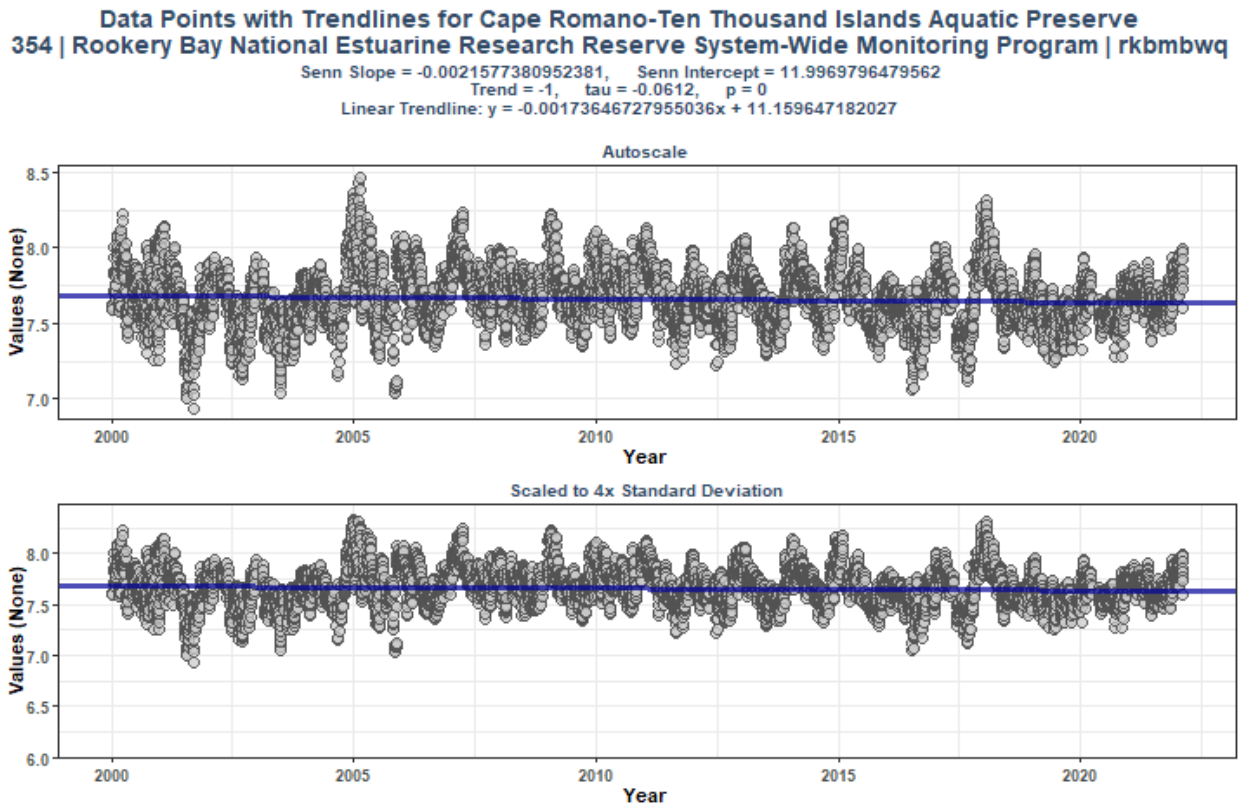
```
if(n==0){
   print("There are no monitoring locations that qualify.")
} else {
   for (i in 1:n) {
      plot_data <- data[data$Use_In_Analysis == TRUE &
                                    data$MonitoringID == Mon_IDs[i],]
      year_lower <- min(plot_data$Year)
      year_upper <- max(plot_data$Year)
      min_RV <- min(plot_data$ResultValue)
      mn_RV <- mean(plot_data$ResultValue[plot_data$ResultValue <
                                       quantile(plot_data$ResultValue, 0.98)])
```

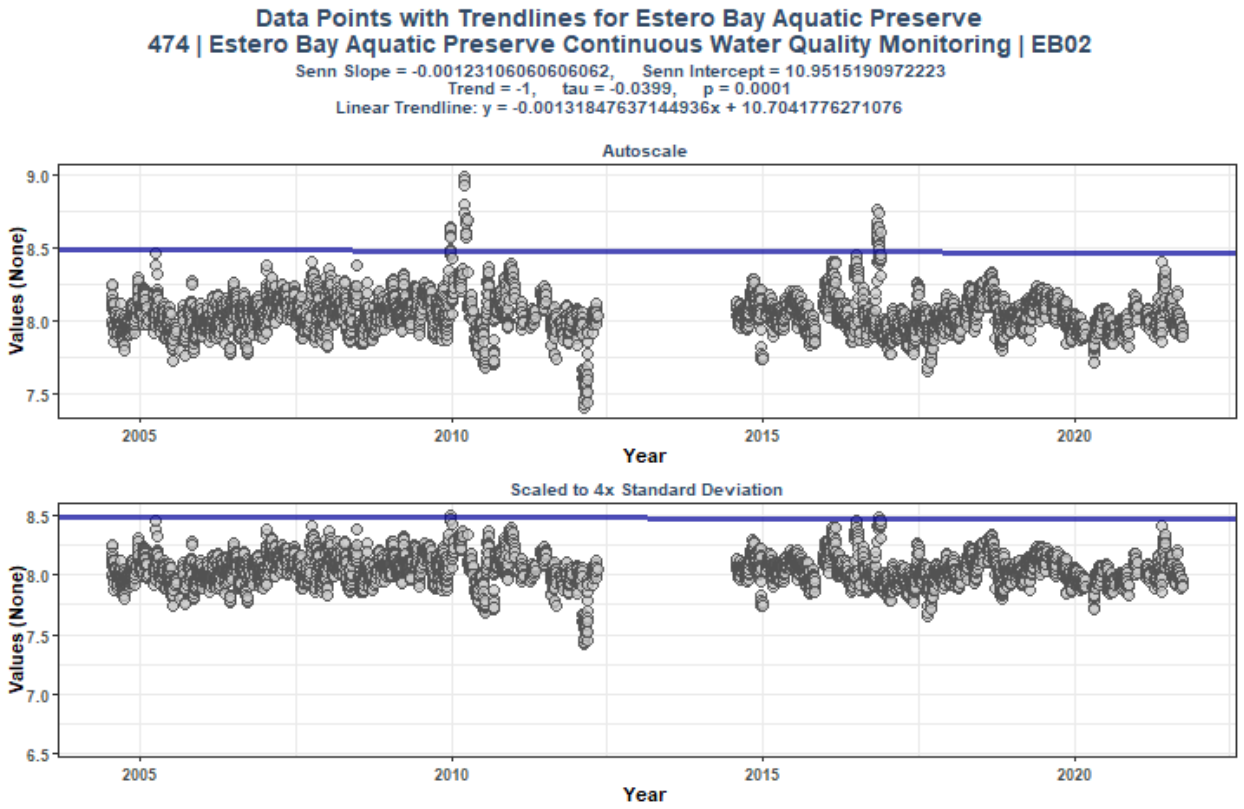
```
sd_RV <- sd(plot_data$ResultValue[plot_data$ResultValue <
                                  quantile(plot_data$ResultValue, 0.98)])
x_scale <- ifelse(year_upper - year_lower > 30, 10, 5)
y_scale <- mn_RV + 4 * sd_RV

tau <- KT.Stats$tau[KT.Stats$MonitoringID == Mon_IDs[i]]
s_slope <- KT.Stats$SennSlope[KT.Stats$MonitoringID == Mon_IDs[i]]
s_int <- KT.Stats$SennIntercept[KT.Stats$MonitoringID == Mon_IDs[i]]
trend <- KT.Stats$Trend[KT.Stats$MonitoringID == Mon_IDs[i]]
p <- KT.Stats$p[KT.Stats$MonitoringID == Mon_IDs[i]]

model <- lm(ResultValue ~ DecDate,
            data = plot_data)
m_int <- coef(model)[[1]]
m_slope <- coef(model)[[2]]
rm(model)
MA_name <- KT.Stats$ManagedAreaName[KT.Stats$MonitoringID == Mon_IDs[i]]
Mon_name <- paste(KT.Stats$ProgramID[KT.Stats$MonitoringID == Mon_IDs[i]],
   KT.Stats$ProgramName[KT.Stats$MonitoringID == Mon_IDs[i]],
   KT.Stats$ProgramLocationID[KT.Stats$MonitoringID == Mon_IDs[i]],
   sep = " | ")

p1 <- ggplot(data = plot_data,
             aes(x = DecDate, y = ResultValue)) +
   geom_point(shape=21, size=3, color="#333333", fill="#cccccc",
              alpha=0.75) +
   geom_abline(aes(slope=s_slope, intercept=s_int),
               color="#000099", size=1.2, alpha=0.7) +
   labs(subtitle = "Autoscale",
        x = "Year", y = paste0("Values (", unit, ")")) +
   plot_theme

p2 <- ggplot(data = plot_data,
             aes(x = DecDate, y = ResultValue)) +
   geom_point(shape=21, size=3, color="#333333", fill="#cccccc",
              alpha=0.75) +
   geom_abline(aes(slope=s_slope, intercept=s_int),
               color="#000099", size=1.2, alpha=0.7) +
   ylim(min_RV-0.1*y_scale, y_scale) +
   labs(subtitle = "Scaled to 4x Standard Deviation",
        x = "Year", y = paste0("Values (", unit, ")")) +
   plot_theme

KTset <- ggarrange(p1, p2, ncol = 1, heights = c(1, 1))

p0 <- ggplot() + labs(title = paste0("Data Points with Trendlines for ",
                                     MA_name, "\n", Mon_name),
                      subtitle =paste0("Senn Slope = ", s_slope,
                                       ",     Senn Intercept = ", s_int,
                                       "\nTrend = ", trend,
                                       ",     tau = ", tau,
                                       ",     p = ", p,
                                       "\nLinear Trendline: ",
```

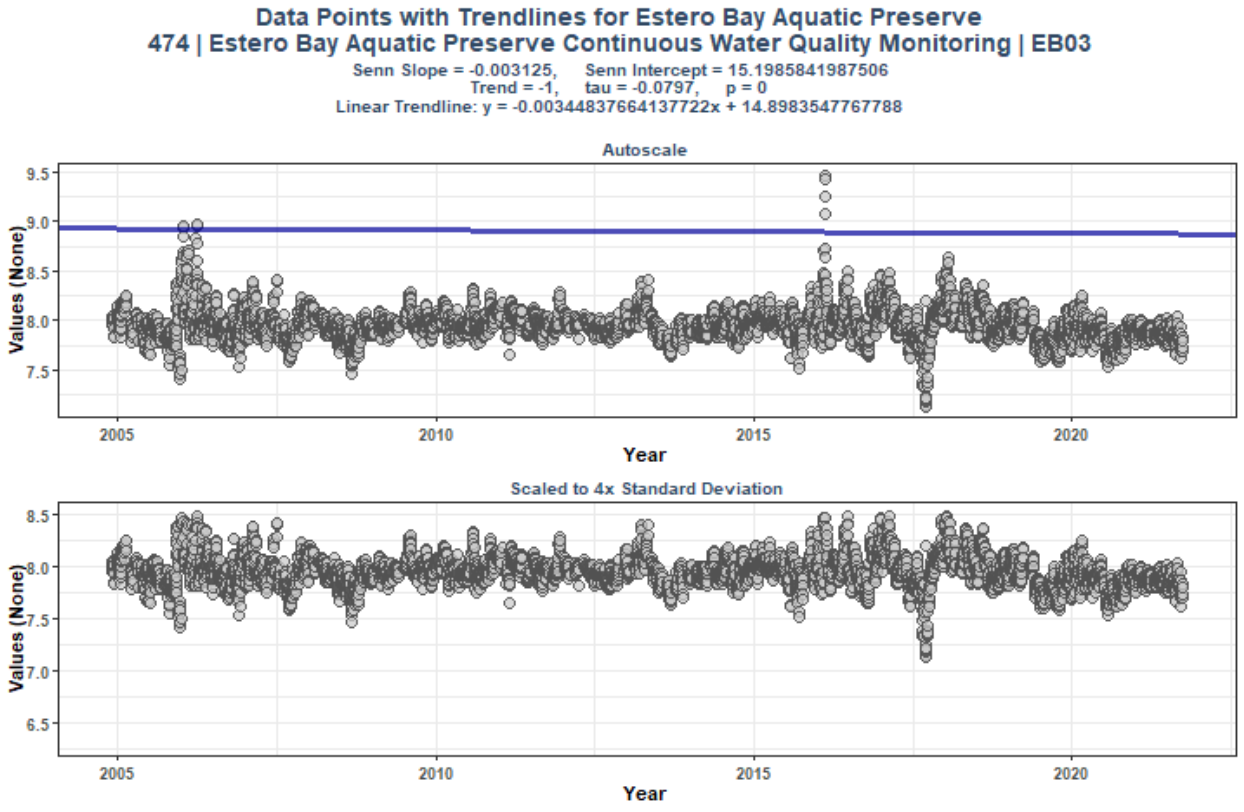
```
                                          "y = ", m_slope,"x + ",m_int)) +
        plot_theme + theme(panel.border = element_blank(),
                           panel.grid.major = element_blank(),
                           panel.grid.minor = element_blank(),
                           axis.line = element_blank())

      print(ggarrange(p0, KTset, ncol = 1, heights = c(0.20, 1)))
      rm(plot_data)
      rm(KTset, leg)
   }
}
```

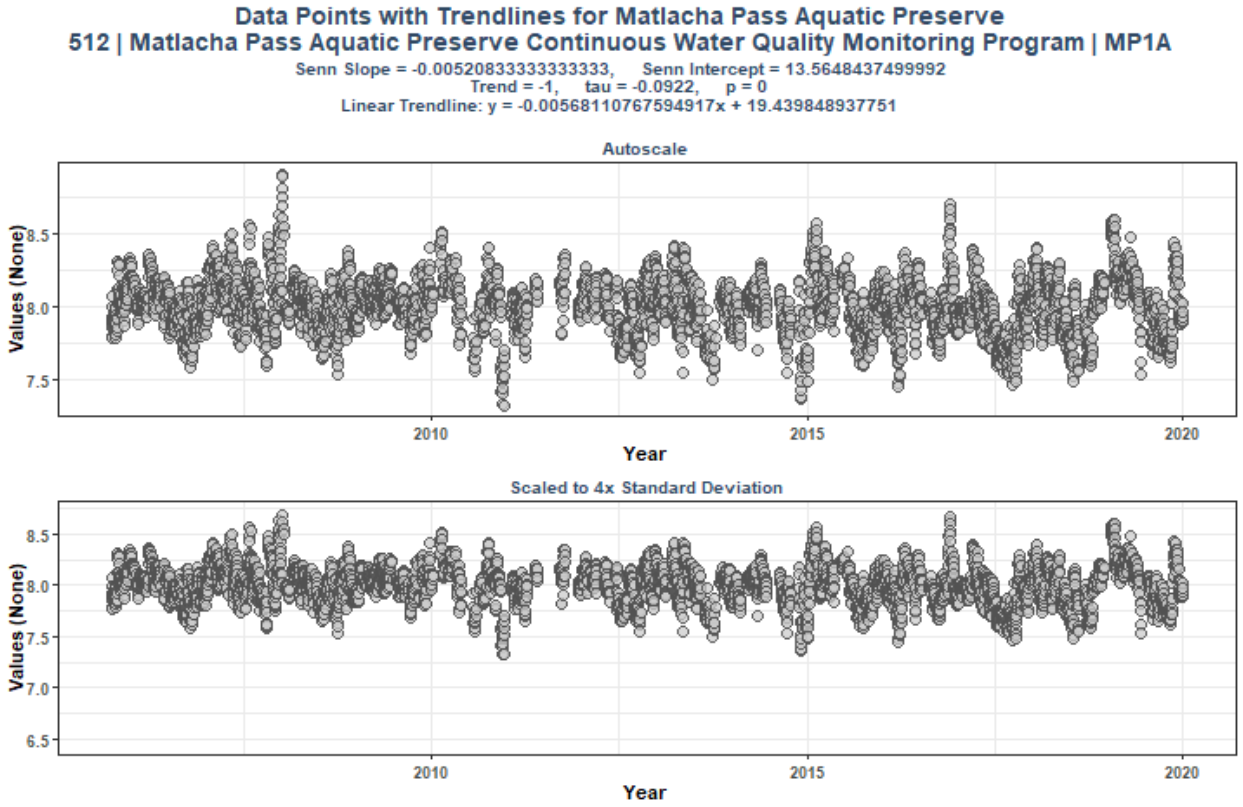


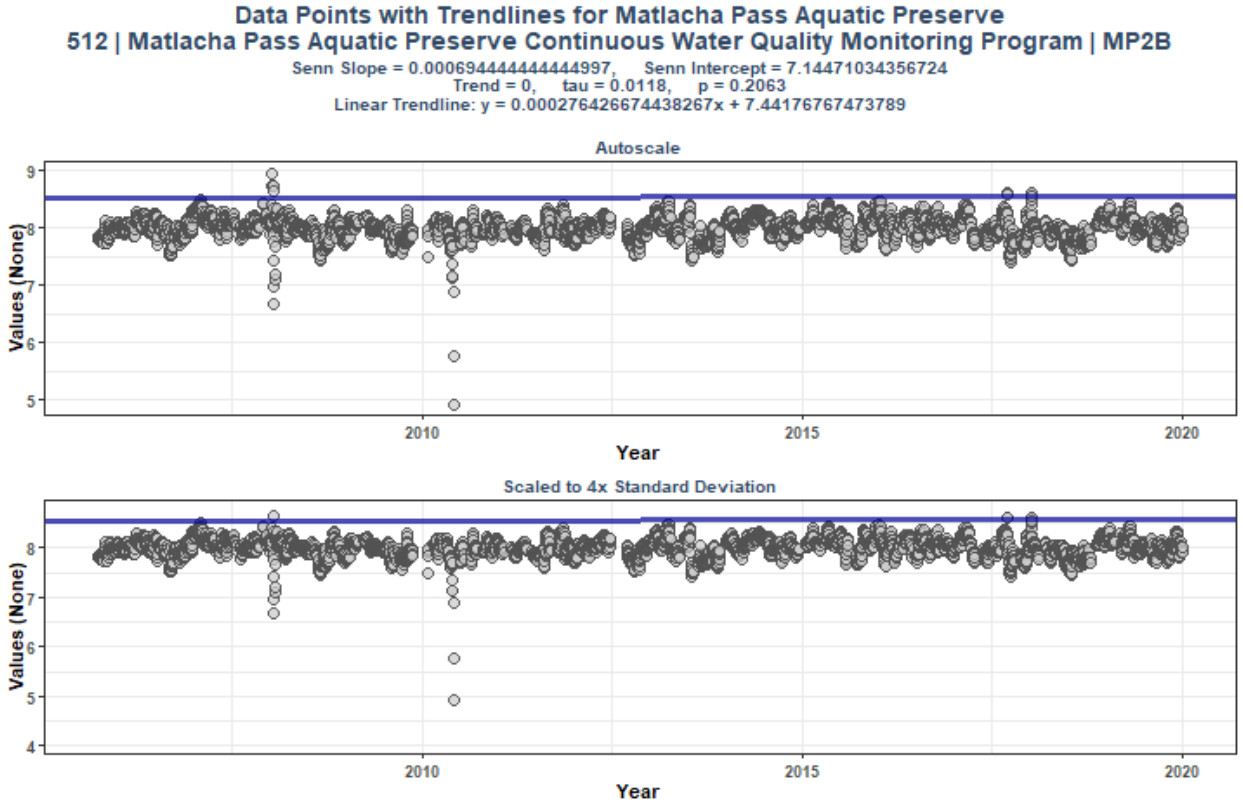

Data Points with Trendlines for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfuwq
Senn Slope = -0.00156249999999991, Senn Intercept = 12.2007599317816
Trend = -1, tau = -0.0479, p = 0
Linear Trendline: y = -0.00254214231578646x + 12.8125920982054
Autoscale
Values (None)
Year
Scaled to 4x Standard Deviation
Values (None)
Year


Data Points with Trendlines for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbmbwq
Senn Slope = -0.0021577380952381, Senn Intercept = 11.9969796479562
Trend = -1, tau = -0.0612, p = 0
Linear Trendline: y = -0.00173646727955036x + 11.159647182027
Autoscale
Values (None)
Year
Scaled to 4x Standard Deviation
Values (None)
Year


Data Points with Trendlines for Estero Bay Aquatic Preserve
474 | Estero Bay Aquatic Preserve Continuous Water Quality Monitoring | EB02
Senn Slope = -0.00123106060606062, Senn Intercept = 10.9515190972223
Trend = -1, tau = -0.0399, p = 0.0001
Linear Trendline: y = -0.00131847637144936x + 10.7041776271076
Autoscale
Values (None)
Year
Scaled to 4x Standard Deviation
Values (None)
Year

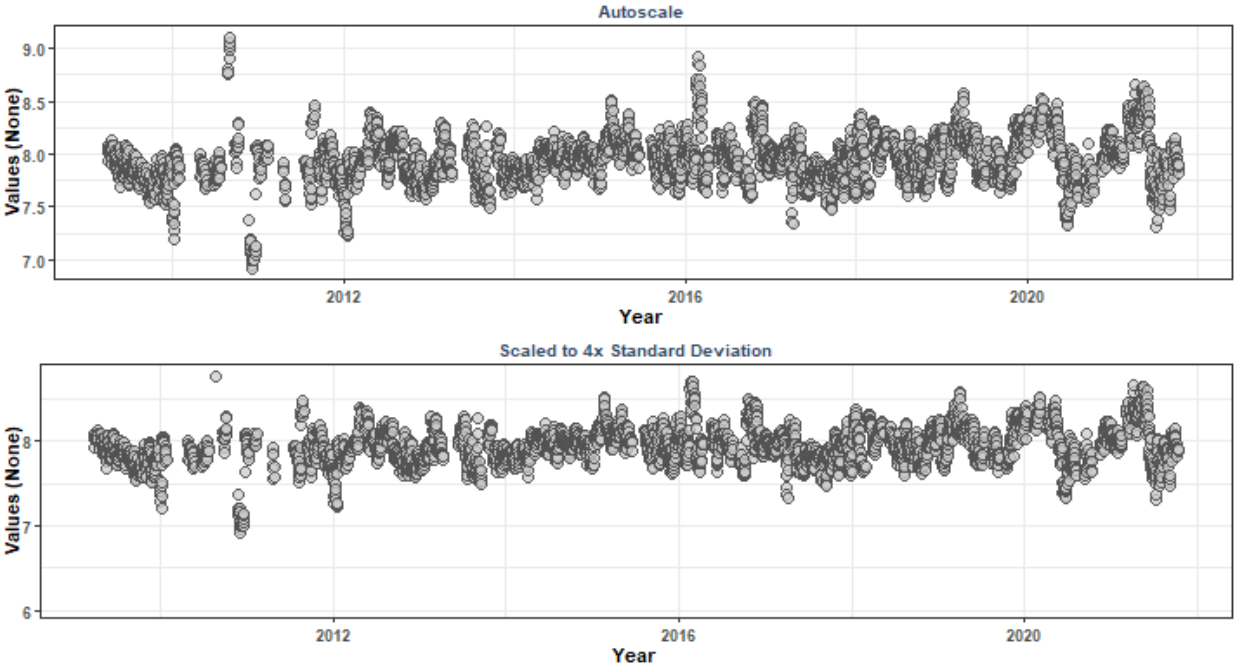

Data Points with Trendlines for Estero Bay Aquatic Preserve
474 | Estero Bay Aquatic Preserve Continuous Water Quality Monitoring | EB03
Senn Slope = -0.003125, Senn Intercept = 15.1985841987506
Trend = -1, tau = -0.0797, p = 0
Linear Trendline: y = -0.00344837664137722x + 14.8983547767788
Autoscale
Values (None)
Year
Scaled to 4x Standard Deviation
Values (None)
Year


Data Points with Trendlines for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP1A
Senn Slope = -0.00520833333333333, Senn Intercept = 13.5648437499992
Trend = -1, tau = -0.0922, p = 0
Linear Trendline: y = -0.00568110767594917x + 19.439848937751
Autoscale
Values (None)
8.5
8.0
7.5
2010
2015
2020
Year
Scaled to 4x Standard Deviation
Values (None)
8.5
8.0
7.5
7.0
6.5
2010
2015
2020
Year


Data Points with Trendlines for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP2B
Senn Slope = 0.000694444444444997, Senn Intercept = 7.14471034356724
Trend = 0, tau = 0.0118, p = 0.2063
Linear Trendline: y = 0.000276426674438267x + 7.44176767473789
Autoscale
Values (None)
9
8
7
6
5
2010
2015
2020
Year
Scaled to 4x Standard Deviation
Values (None)
8
7
6
5
4
2010
2015
2020
Year

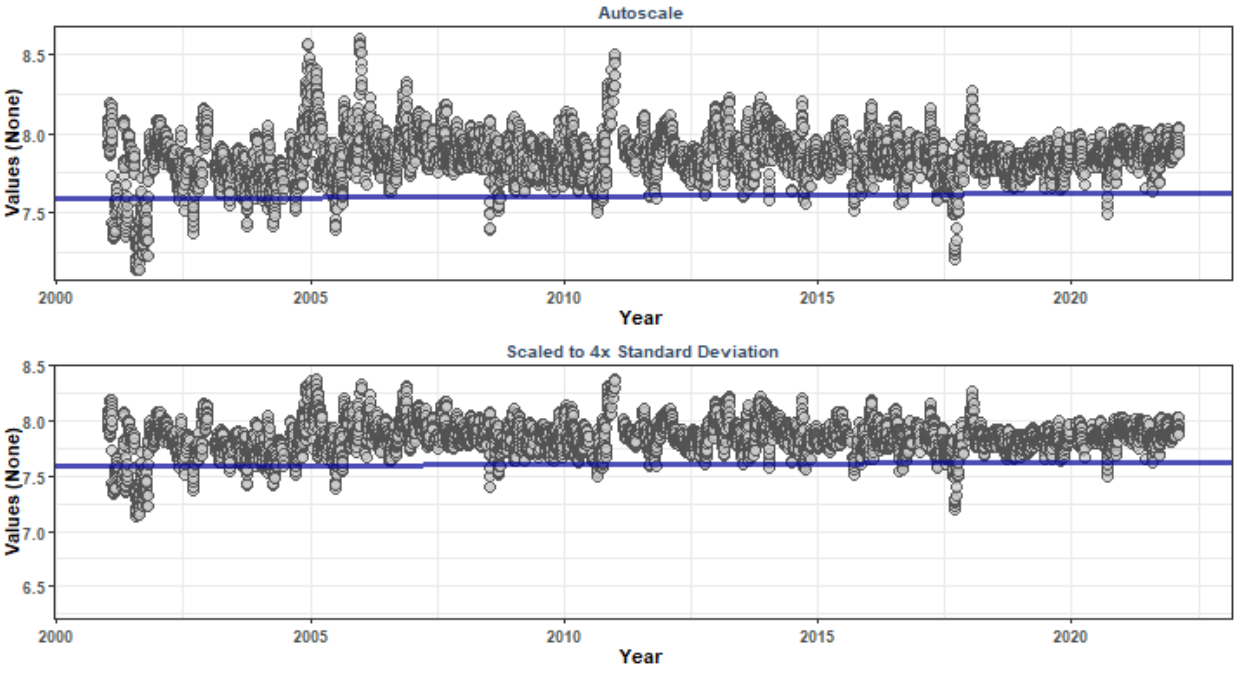
Data Points with Trendlines for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP3C

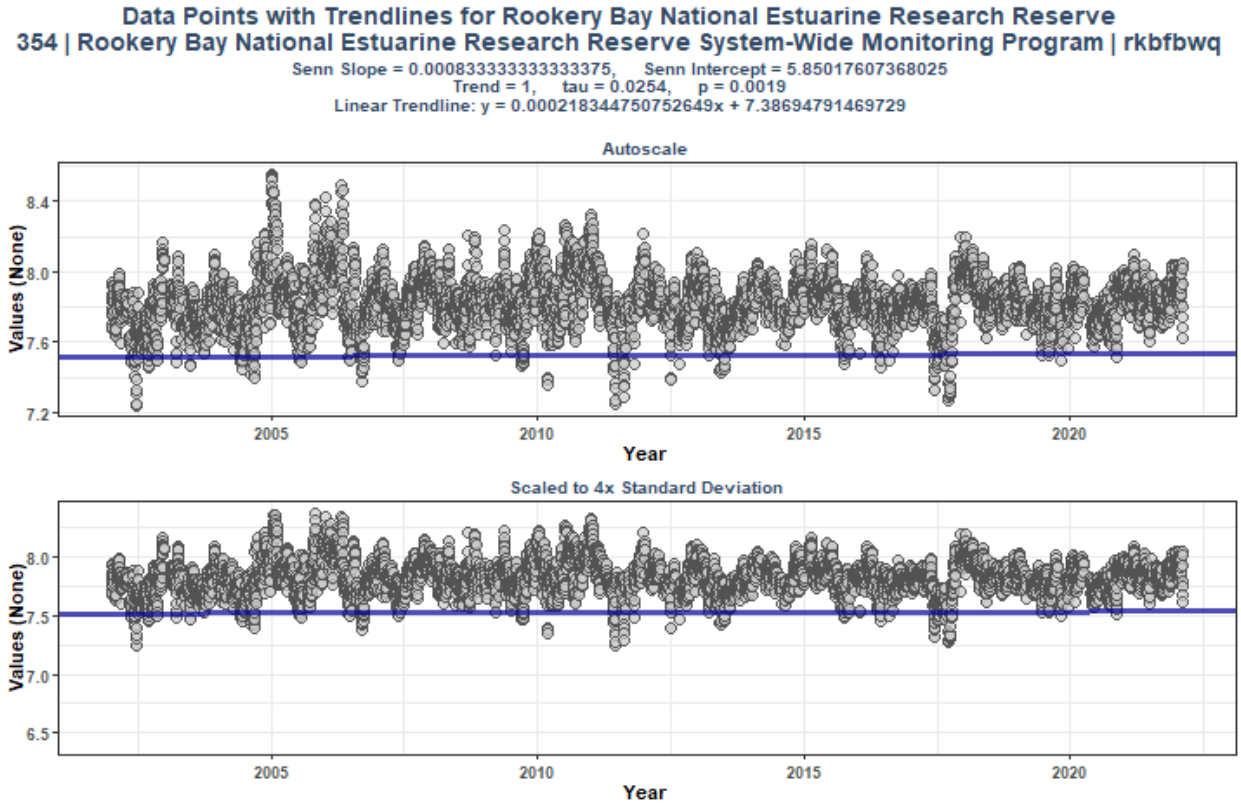
Senn Slope = 0.01484375, Senn Intercept = -32.9970744680855
Trend = 1, tau = 0.1648, p = 0
Linear Trendline: y = 0.0150905375442153x + -22.4786922619601

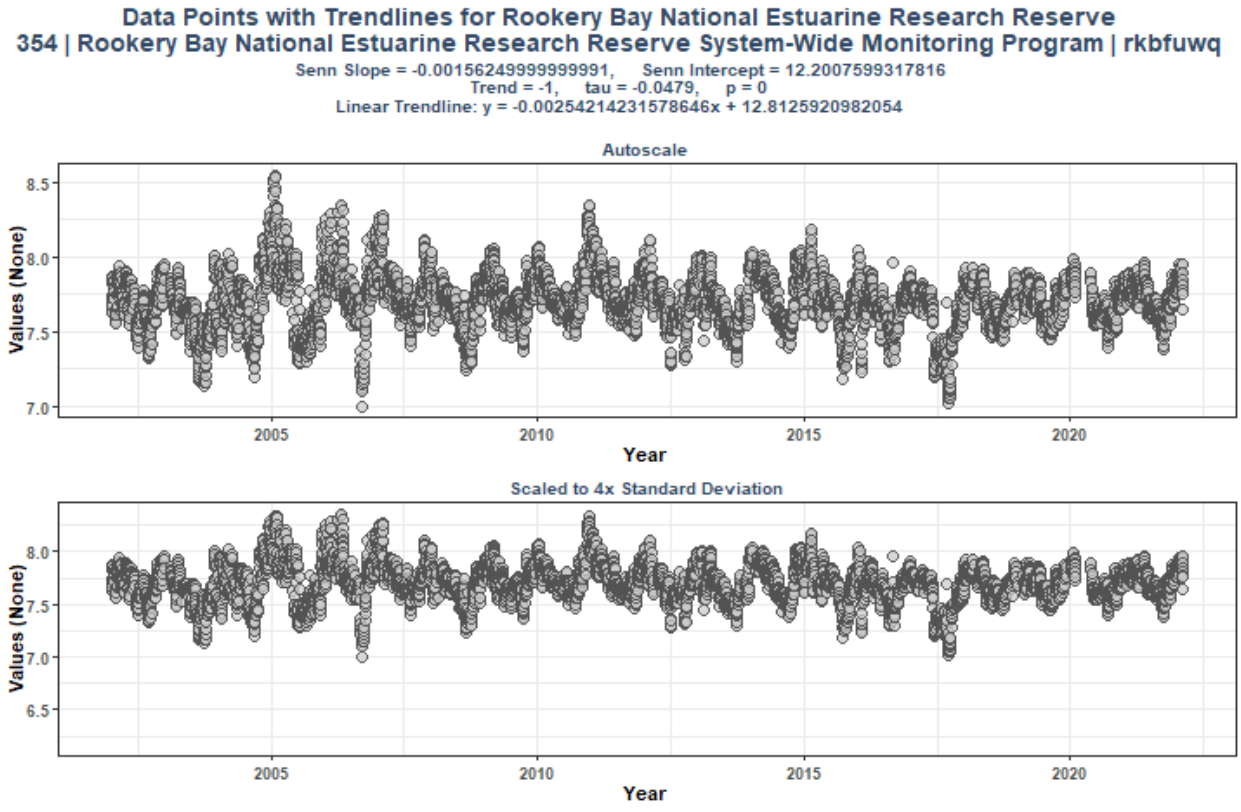


Data Points with Trendlines for Rookery Bay Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkblhwq

Senn Slope = 0.00166666666666666, Senn Intercept = 4.25260416666662
Trend = 1, tau = 0.053, p = 0
Linear Trendline: y = 0.00255018895643459x + 2.7200447141202

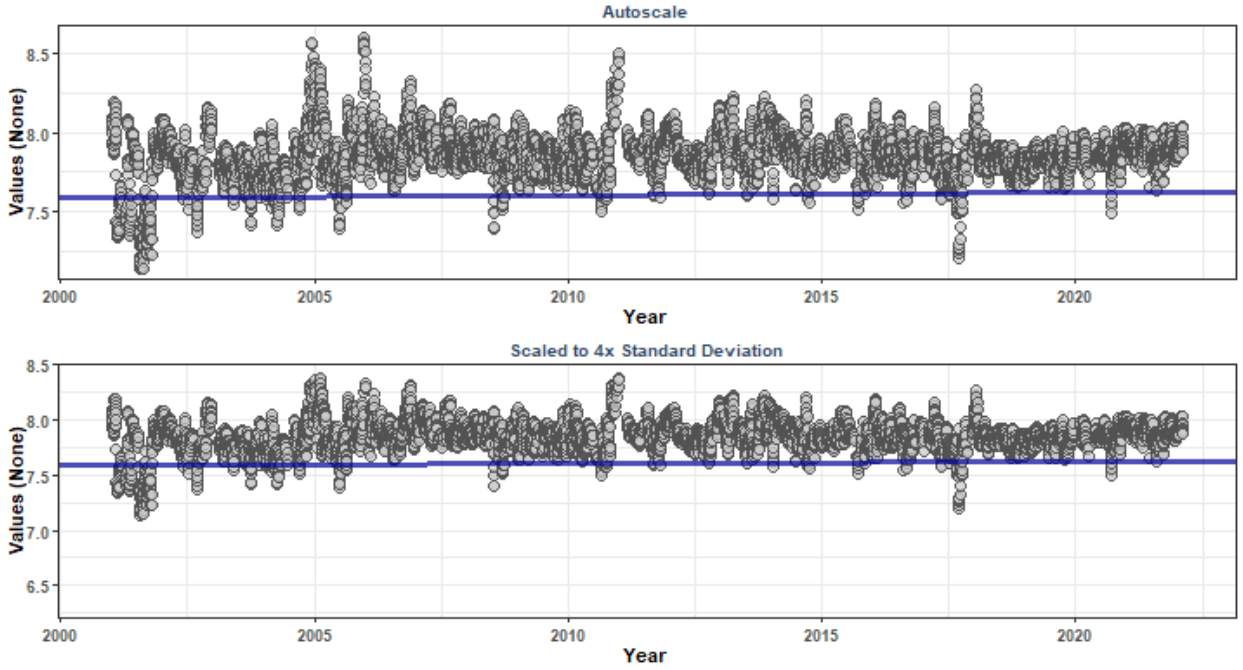



Data Points with Trendlines for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfbwq
Senn Slope = 0.000833333333333375, Senn Intercept = 5.85017607368025
Trend = 1, tau = 0.0254, p = 0.0019
Linear Trendline: y = 0.0002183447507526 49x + 7.38694791469729
Autoscale
Values (None)
8.4
8.0
7.6
7.2
2005
2010
2015
2020
Year
Scaled to 4x Standard Deviation
Values (None)
8.0
7.5
7.0
6.5
2005
2010
2015
2020
Year


Data Points with Trendlines for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfuwq
Senn Slope = -0.00156249999999991, Senn Intercept = 12.2007599317816
Trend = -1, tau = -0.0479, p = 0
Linear Trendline: y = -0.0025421423157864 6x + 12.8125920982054
Autoscale
Values (None)
8.5
8.0
7.5
7.0
2005
2010
2015
2020
Year
Scaled to 4x Standard Deviation
Values (None)
8.0
7.5
7.0
6.5
2005
2010
2015
2020
Year

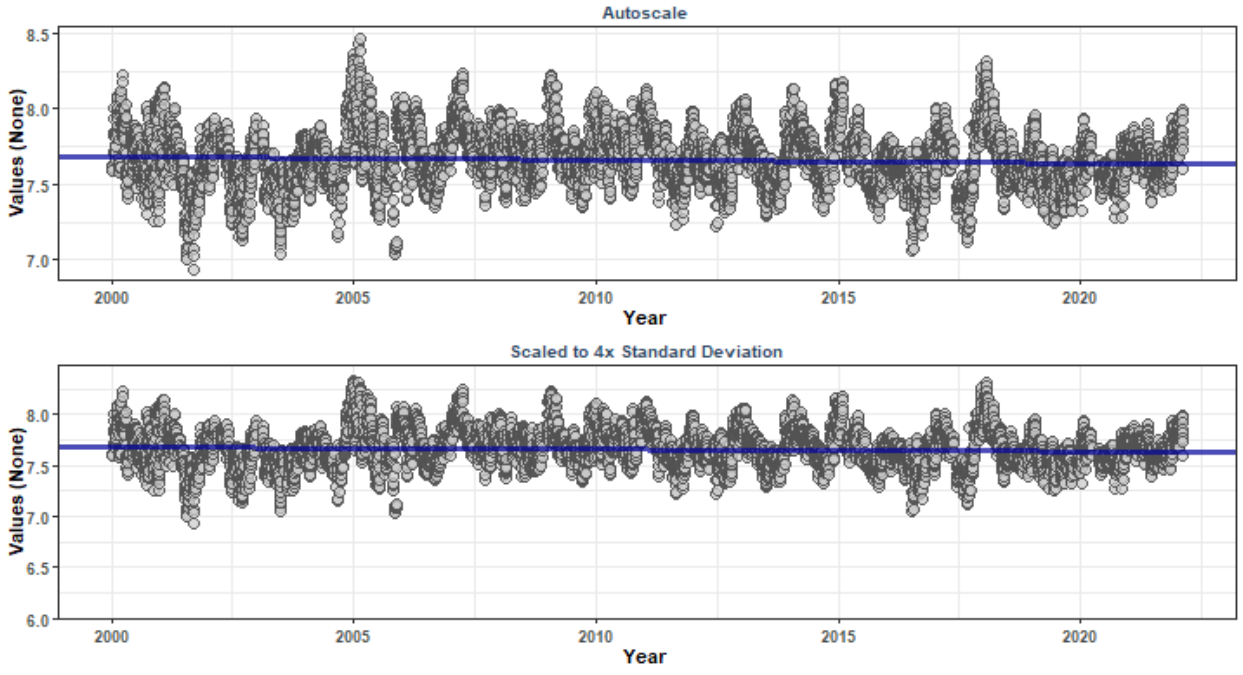
Data Points with Trendlines for Rookery Bay National Estuarine Research Reserve 354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkblhwq

Senn Slope = 0.00166666666666666, Senn Intercept = 4.25260416666662
Trend = 1, tau = 0.053, p = 0
Linear Trendline: y = 0.00255018895643459x + 2.7200447141202



Data Points with Trendlines for Rookery Bay National Estuarine Research Reserve 354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbmbwq

Senn Slope = -0.0021577380952381, Senn Intercept = 11.9969796479562
Trend = -1, tau = -0.0612, p = 0
Linear Trendline: y = -0.00173646727955036x + 11.159647182027



Appendix IV: Monitoring Location Summary Box Plots

Data is taken and grouped by `MonitoringID`. The scripts that create plots follow this format

1. Use the data set that only has `Use_In_Analysis` of `TRUE` for the desired monitoring location
2. Determine the earliest and latest year of the data to create x-axis scale and intervals
3. Determine the minimum, mean, and standard deviation for the data to be used for y-axis scales
    - Excludes the top 2% of values to reduce the impact of extreme outliers on the y-axis scale
4. Set what values are to be used for the x-axis, y-axis, and the variable that should determine groups for the box plots
5. Set the plot type as a box plot with the size of the outlier points
6. Create the title, x-axis, y-axis, and color fill labels
7. Set the y and x limits
8. Make the axis labels bold
9. Plot the arrangement as a set of panels

The following plots are arranged by `MonitoringID` with data grouped by `Year`, then `Year` and `Month`, then finally `Month` only. Each program area will have 3 sets of plots, each with 3 panels in them. Each panel goes as follows:

1. Y-axis autoscaled
2. Y-axis set to be mean + 4 times the standard deviation
3. Y-axis set to be mean + 4 times the standard deviation for most recent 10 years of data

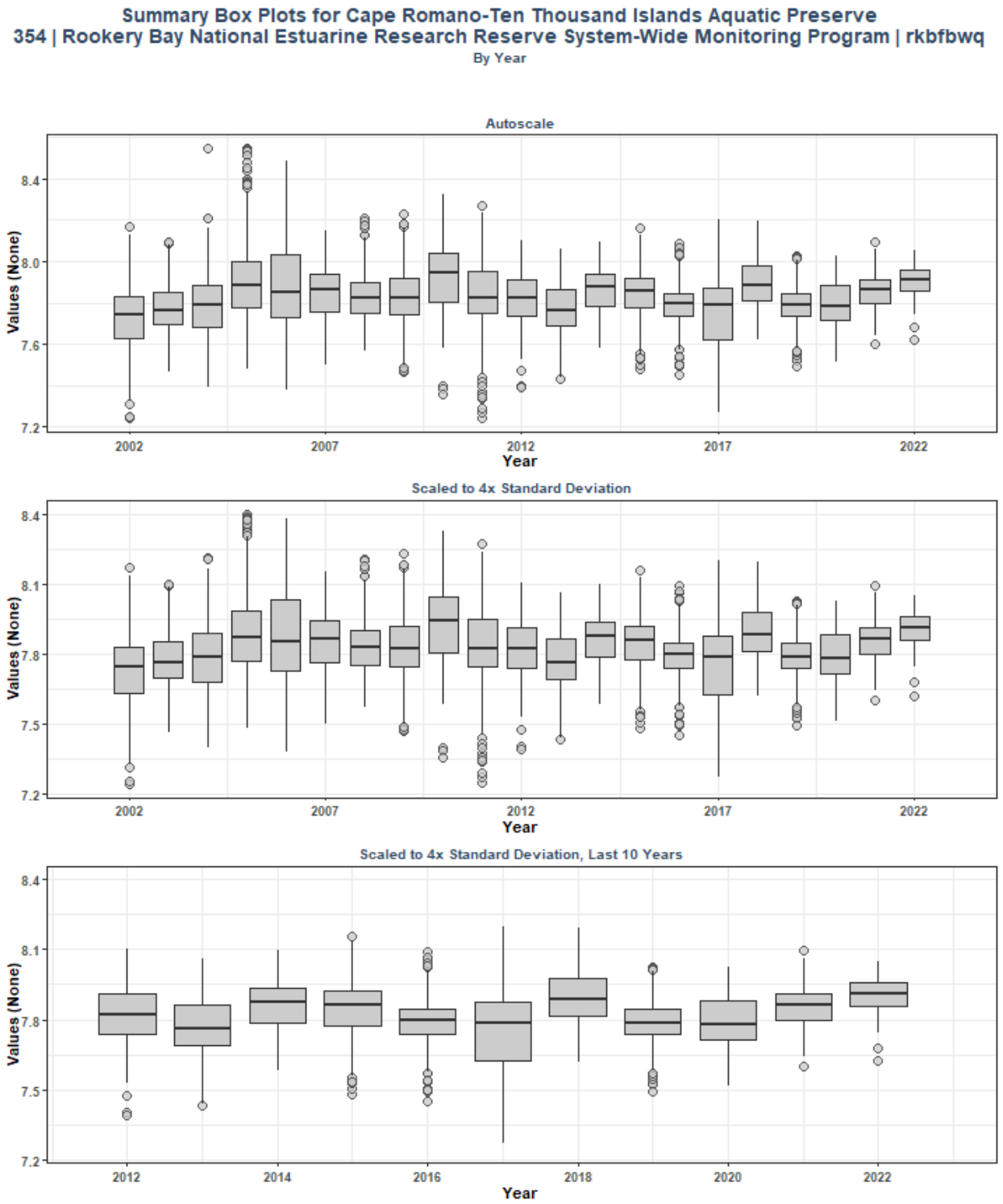
```
if(n==0){
   print("There are no monitoring locations that qualify.")
} else {
   for (i in 1:n) {
      year_lower <- min(data$Year[data$Use_In_Analysis == TRUE &
                                  data$MonitoringID == Mon_IDs[i]])
      year_upper <- max(data$Year[data$Use_In_Analysis == TRUE &
                                  data$MonitoringID == Mon_IDs[i]])
      min_RV <- min(data$ResultValue[data$Use_In_Analysis == TRUE &
                                     data$MonitoringID == Mon_IDs[i]])
      mn_RV <- mean(data$ResultValue[data$Use_In_Analysis == TRUE &
                                     data$MonitoringID == Mon_IDs[i] &
                                     data$ResultValue <
                                     quantile(data$ResultValue, 0.98)])
      sd_RV <- sd(data$ResultValue[data$Use_In_Analysis == TRUE &
                                   data$MonitoringID == Mon_IDs[i] &
                                   data$ResultValue <
                                   quantile(data$ResultValue, 0.98)])
      x_scale <- ifelse(year_upper - year_lower > 30, 10, 5)
      y_scale <- mn_RV + 4 * sd_RV
      MA_name <- KT.Stats$ManagedAreaName[KT.Stats$MonitoringID == Mon_IDs[i]]
      Mon_name <- paste(KT.Stats$ProgramID[KT.Stats$MonitoringID == Mon_IDs[i]],
                        KT.Stats$ProgramName[KT.Stats$MonitoringID == Mon_IDs[i]],
                        KT.Stats$ProgramLocationID[KT.Stats$MonitoringID == Mon_IDs[i]],
                        sep = " | ")

      ##Year plots
      p1 <- ggplot(data = data[data$Use_In_Analysis == TRUE &
```

```
                              data$MonitoringID == Mon_IDs[i], ],
              aes(x = Year, y = ResultValue, group = Year)) +
   geom_boxplot(color="#333333", fill="#cccccc", outlier.shape=21,
                outlier.size=3, outlier.color="#333333",
                outlier.fill="#cccccc", outlier.alpha=0.75) +
   labs(subtitle = "Autoscale",
        x = "Year", y = paste0("Values (", unit, ")")) +
   scale_x_continuous(limits = c(year_lower - 1, year_upper + 1),
                      breaks = rev(seq(year_upper,
                                       year_lower, -x_scale))) +
   plot_theme

p2 <- ggplot(data = data[data$Use_In_Analysis == TRUE &
                              data$MonitoringID == Mon_IDs[i], ],
              aes(x = Year, y = ResultValue, group = Year)) +
   geom_boxplot(color="#333333", fill="#cccccc", outlier.shape=21,
                outlier.size=3, outlier.color="#333333",
                outlier.fill="#cccccc", outlier.alpha=0.75) +
   labs(subtitle = "Scaled to 4x Standard Deviation",
        x = "Year", y = paste0("Values (", unit, ")")) +
   ylim(min_RV, y_scale) +
   scale_x_continuous(limits = c(year_lower - 1, year_upper + 1),
                      breaks = rev(seq(year_upper,
                                       year_lower, -x_scale))) +
   plot_theme

p3 <- ggplot(data = data[data$Use_In_Analysis == TRUE &
                              data$MonitoringID == Mon_IDs[i] &
                              data$Year>=year_upper-10, ],
              aes(x = Year, y = ResultValue, group = Year)) +
   geom_boxplot(color="#333333", fill="#cccccc", outlier.shape=21,
                outlier.size=3, outlier.color="#333333",
                outlier.fill="#cccccc", outlier.alpha=0.75) +
   labs(subtitle = "Scaled to 4x Standard Deviation, Last 10 Years",
        x = "Year", y = paste0("Values (", unit, ")")) +
   ylim(min_RV, y_scale) +
   scale_x_continuous(limits = c(year_upper - 10.5, year_upper + 1),
                      breaks = rev(seq(year_upper, year_upper - 10,-2))) +
   plot_theme

Yset <- ggarrange(p1, p2, p3, ncol = 1)

p0 <- ggplot() + labs(title = paste0("Summary Box Plots for ",
                                     MA_name, "\n", Mon_name),
                      subtitle = "By Year") +
   plot_theme + theme(panel.border = element_blank(),
                      panel.grid.major = element_blank(),
                      panel.grid.minor = element_blank(),
                      axis.line = element_blank())


## Year & Month Plots
p4 <- ggplot(data = data[data$Use_In_Analysis == TRUE &
```

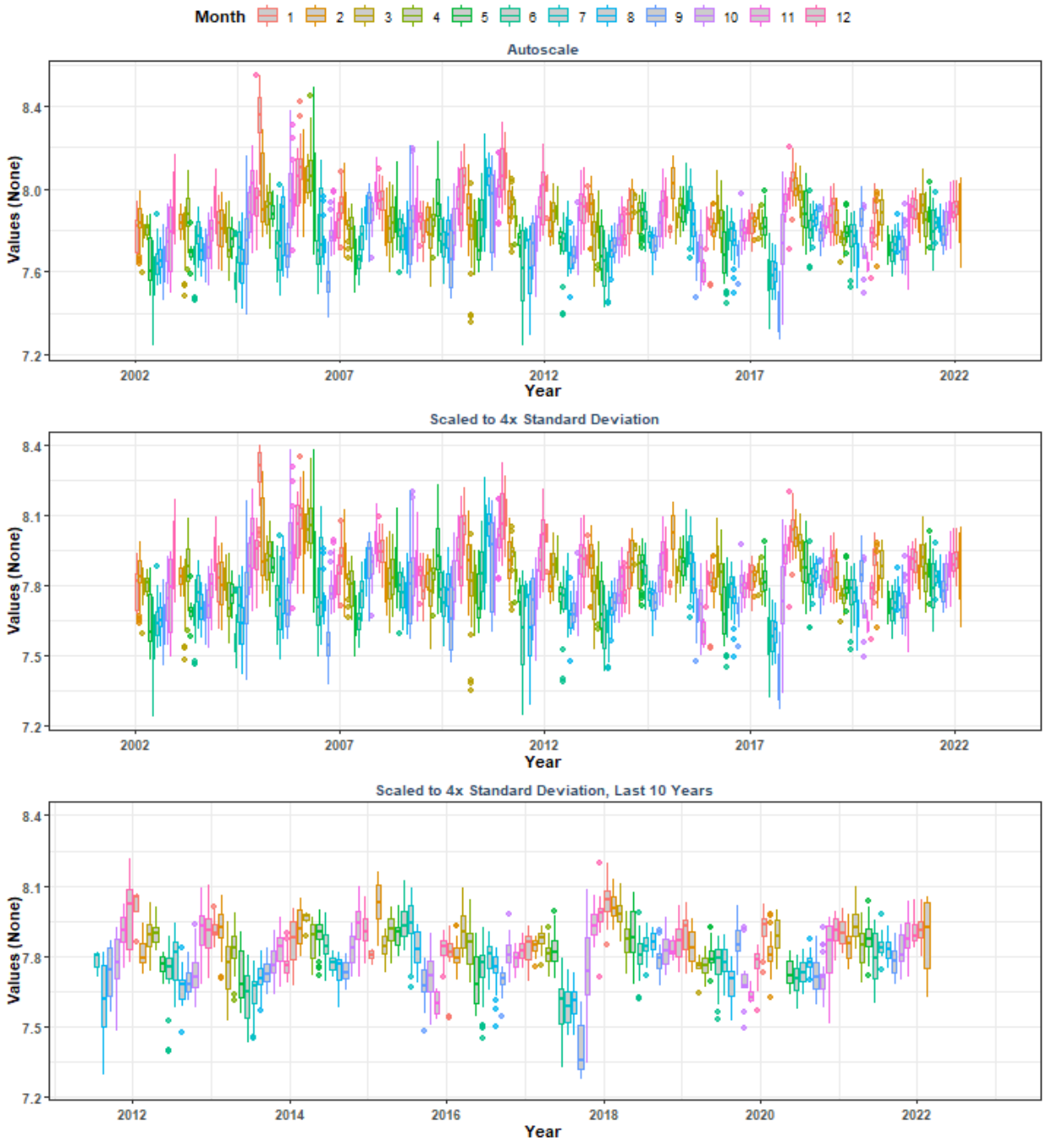
```
                              data$MonitoringID == Mon_IDs[i], ],
              aes(x = YearMonthDec, y = ResultValue,
                  group = YearMonth, color = as.factor(Month))) +
   geom_boxplot(fill="#cccccc", outlier.size=1.5, outlier.alpha=0.75) +
   labs(subtitle = "Autoscale",
        x = "Year", y = paste0("Values (", unit, ")"), color = "Month") +
   scale_x_continuous(limits = c(year_lower - 1, year_upper + 1),
                      breaks = rev(seq(year_upper,
                                       year_lower, -x_scale))) +
   plot_theme +
   theme(legend.position = "none")

p5 <- ggplot(data = data[data$Use_In_Analysis == TRUE &
                              data$MonitoringID == Mon_IDs[i], ],
              aes(x = YearMonthDec, y = ResultValue,
                  group = YearMonth, color = as.factor(Month))) +
   geom_boxplot(fill="#cccccc", outlier.size=1.5, outlier.alpha=0.75) +
   labs(subtitle = "Scaled to 4x Standard Deviation",
        x = "Year", y = paste0("Values (", unit, ")"), color = "Month") +
   ylim(min_RV, y_scale) +
   scale_x_continuous(limits = c(year_lower - 1, year_upper + 1),
                      breaks = rev(seq(year_upper,
                                       year_lower, -x_scale))) +
   plot_theme +
   theme(legend.position = "top", legend.box = "horizontal") +
   guides(color = guide_legend(nrow = 1))

p6 <- ggplot(data = data[data$Use_In_Analysis == TRUE &
                              data$MonitoringID == Mon_IDs[i], ],
              aes(x = YearMonthDec, y = ResultValue,
                  group = YearMonth, color = as.factor(Month))) +
   geom_boxplot(fill="#cccccc", outlier.size=1.5, outlier.alpha=0.75) +
   labs(subtitle = "Scaled to 4x Standard Deviation, Last 10 Years",
        x = "Year", y = paste0("Values (", unit, ")"), color = "Month") +
   ylim(min_RV, y_scale) +
   scale_x_continuous(limits = c(year_upper - 10.5, year_upper + 1),
                      breaks = rev(seq(year_upper, year_upper - 10,-2))) +
   plot_theme +
   theme(legend.position = "none")

leg1 <- get_legend(p5)
YMset <- ggarrange(leg1, p4, p5 + theme(legend.position = "none"), p6,
                   ncol = 1, heights = c(0.1, 1, 1, 1))

p00 <- ggplot() + labs(title = paste0("Summary Box Plots for ",
                                      MA_name, "\n", Mon_name),
                       subtitle = "By Year & Month") + plot_theme +
   theme(panel.border = element_blank(),
         panel.grid.major = element_blank(),
         panel.grid.minor = element_blank(), axis.line = element_blank())

## Month Plots
p7 <- ggplot(data = data[data$Use_In_Analysis == TRUE &
```

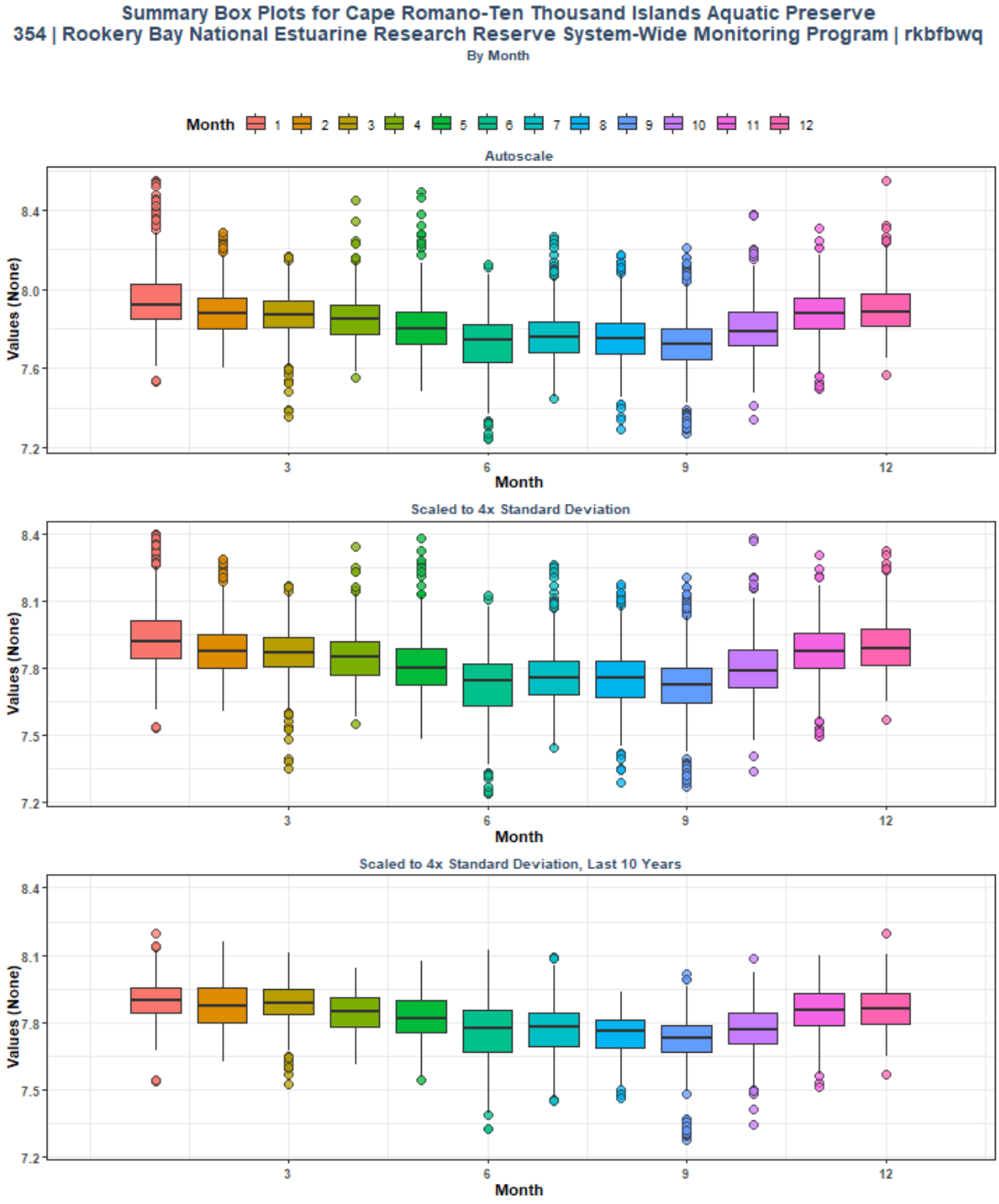
```
                              data$MonitoringID == Mon_IDs[i], ],
              aes(x = Month, y = ResultValue,
                  group = Month, fill = as.factor(Month))) +
   geom_boxplot(color="#333333", outlier.shape=21, outlier.size=3,
                outlier.color="#333333", outlier.alpha=0.75) +
   labs(subtitle = "Autoscale",
        x = "Month", y = paste0("Values (", unit, ")"), fill = "Month") +
   scale_x_continuous(limits = c(0, 13), breaks = seq(3, 12, 3)) +
   plot_theme +
   theme(legend.position = "none")

p8 <- ggplot(data = data[data$Use_In_Analysis == TRUE &
                              data$MonitoringID == Mon_IDs[i], ],
              aes(x = Month, y = ResultValue,
                  group = Month, fill = as.factor(Month))) +
   geom_boxplot(color="#333333", outlier.shape=21, outlier.size=3,
                outlier.color="#333333", outlier.alpha=0.75) +
   labs(subtitle = "Scaled to 4x Standard Deviation",
        x = "Month", y = paste0("Values (", unit, ")"), fill = "Month") +
   ylim(min_RV, y_scale) +
   scale_x_continuous(limits = c(0, 13), breaks = seq(3, 12, 3)) +
   plot_theme +
   theme(legend.position = "top", legend.box = "horizontal") +
   guides(fill = guide_legend(nrow = 1))

p9 <- ggplot(data = data[data$Use_In_Analysis == TRUE &
                              data$MonitoringID == Mon_IDs[i] &
                              data$Year >= year_upper - 10, ],
              aes(x = Month, y = ResultValue,
                  group = Month, fill = as.factor(Month))) +
   geom_boxplot(color="#333333", outlier.shape=21, outlier.size=3,
                outlier.color="#333333", outlier.alpha=0.75) +
   labs(subtitle = "Scaled to 4x Standard Deviation, Last 10 Years",
        x = "Month", y = paste0("Values (", unit, ")"), fill = "Month") +
   ylim(min_RV, y_scale) +
   scale_x_continuous(limits = c(0, 13), breaks = seq(3, 12, 3)) +
   plot_theme +
   theme(legend.position = "none")

leg2 <- get_legend(p8)
Mset <- ggarrange(leg2, p7, p8 + theme(legend.position = "none"), p9,
                  ncol = 1, heights = c(0.1, 1, 1, 1))

p000 <- ggplot() + labs(title = paste0("Summary Box Plots for ",
                                       MA_name, "\n", Mon_name),
                        subtitle = "By Month") + plot_theme +
   theme(panel.border = element_blank(),
         panel.grid.major = element_blank(),
         panel.grid.minor = element_blank(), axis.line = element_blank())

print(ggarrange(p0, Yset, ncol = 1, heights = c(0.1, 1)))
print(ggarrange(p00, YMset, ncol = 1, heights = c(0.1, 1)))
print(ggarrange(p000, Mset, ncol = 1, heights = c(0.1, 1)))
```

```
      rm(plot_data)
      rm(p1, p2, p3, p4, p5, p6, p7, p8, p9, p0, p00, p000, leg1, leg2,
         Yset, YMset, Mset)
   }
}
```



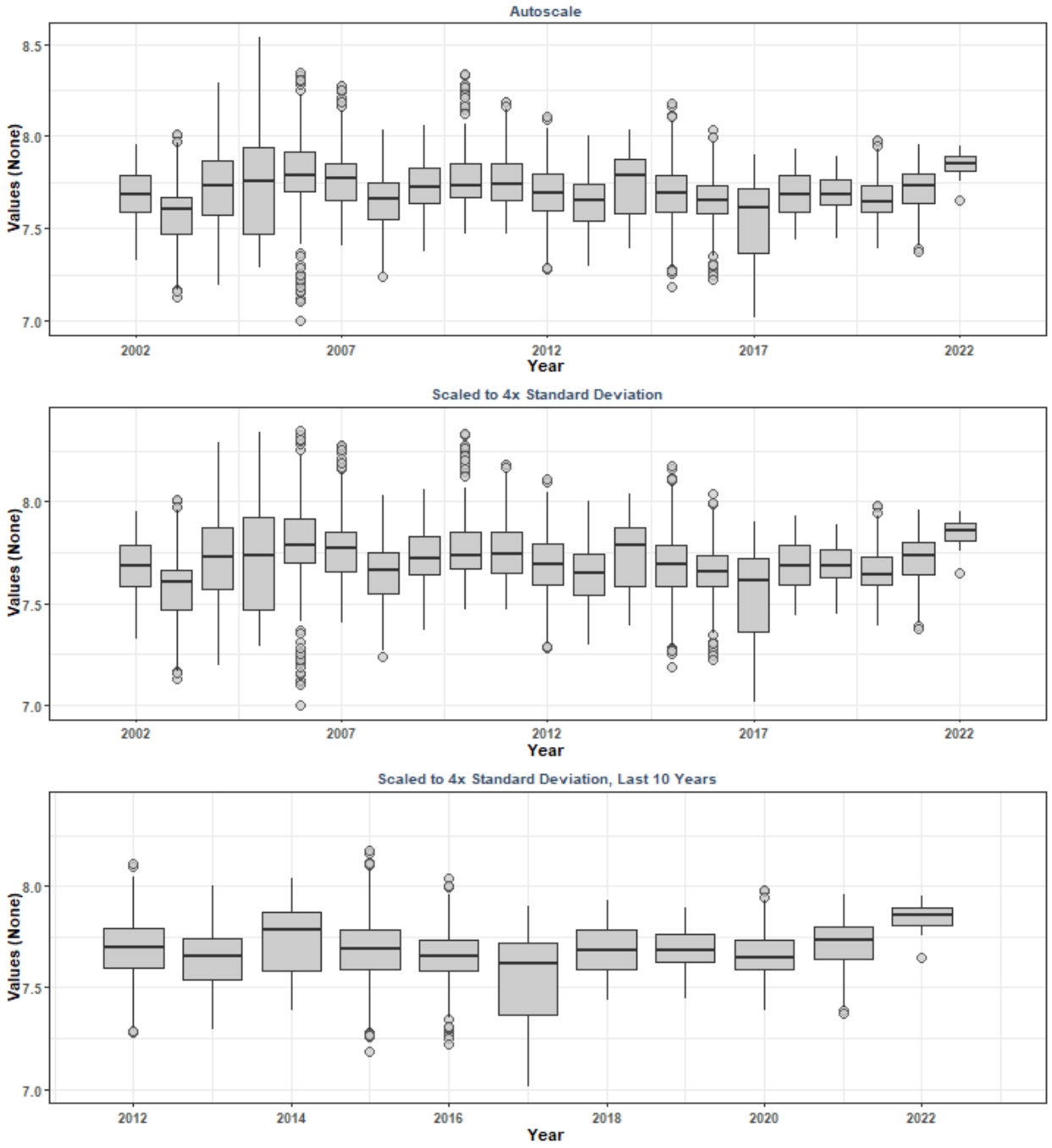
Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfbwq
By Year & Month

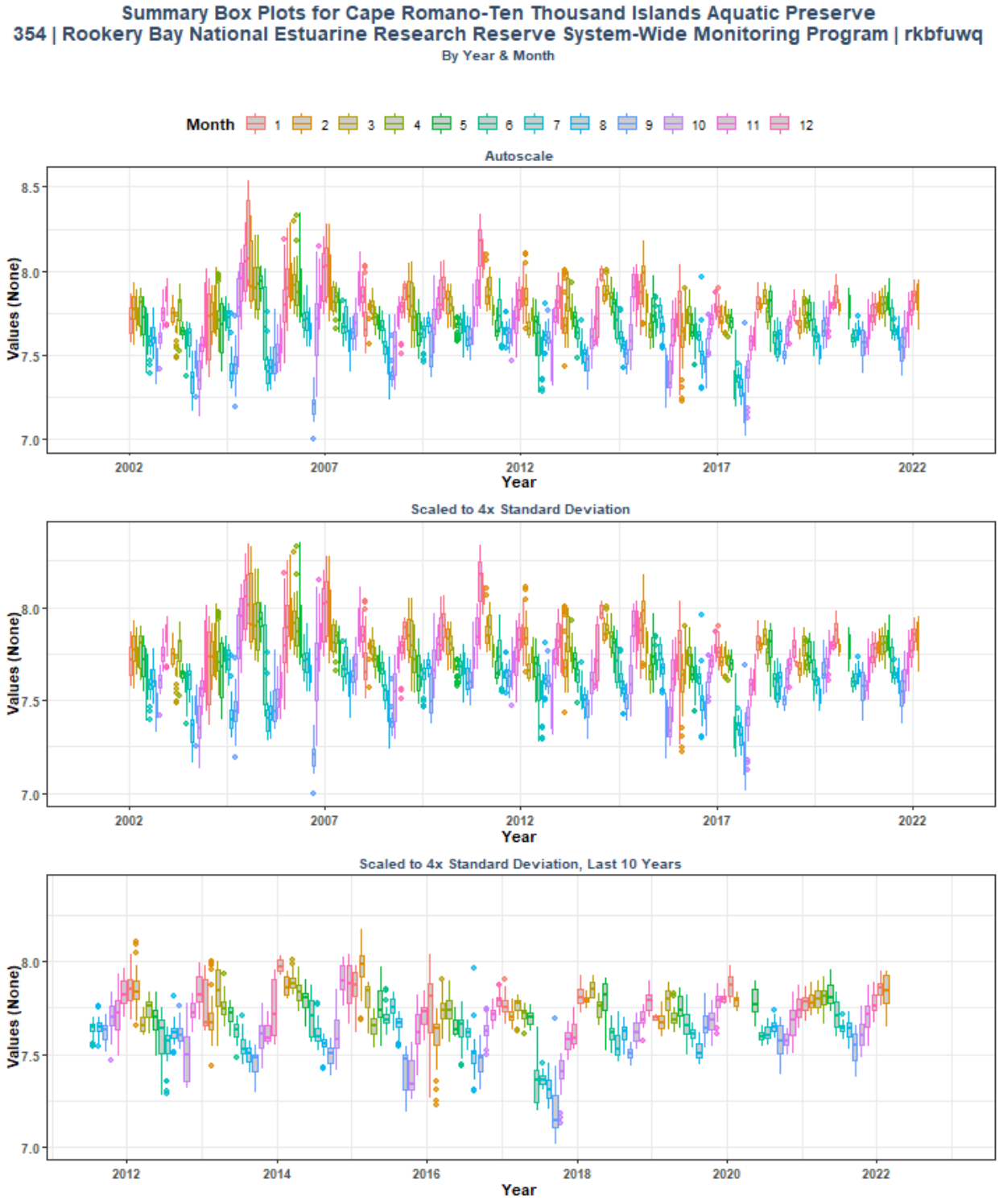



Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfbwq
By Month
Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (None)
8.4
8.0
7.6
7.2
3
6
9
12
Month
Scaled to 4x Standard Deviation
Values (None)
8.4
8.1
7.8
7.5
7.2
3
6
9
12
Month
Scaled to 4x Standard Deviation, Last 10 Years
Values (None)
8.4
8.1
7.8
7.5
7.2
3
6
9
12
Month

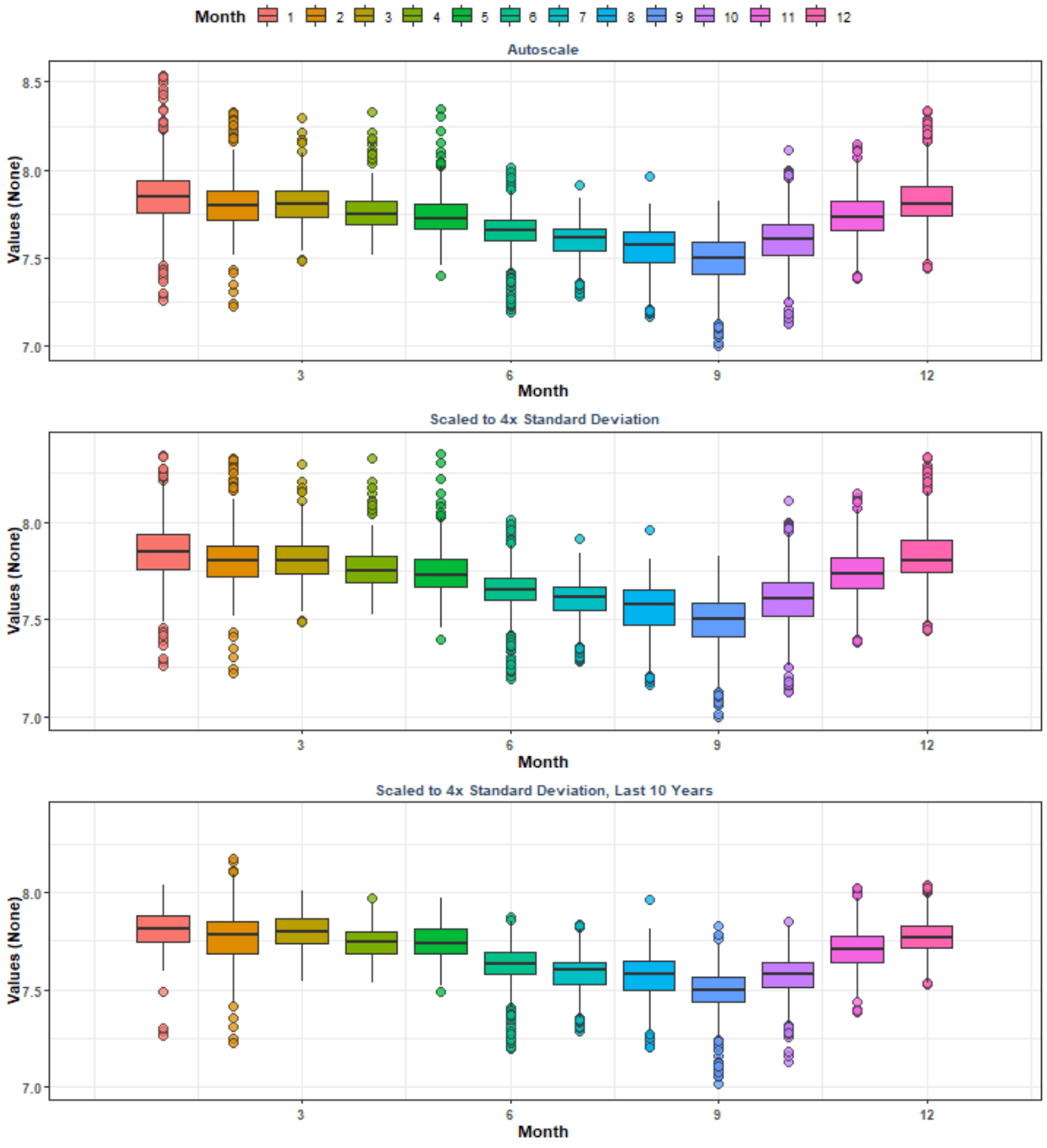
Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfuwq

By Year

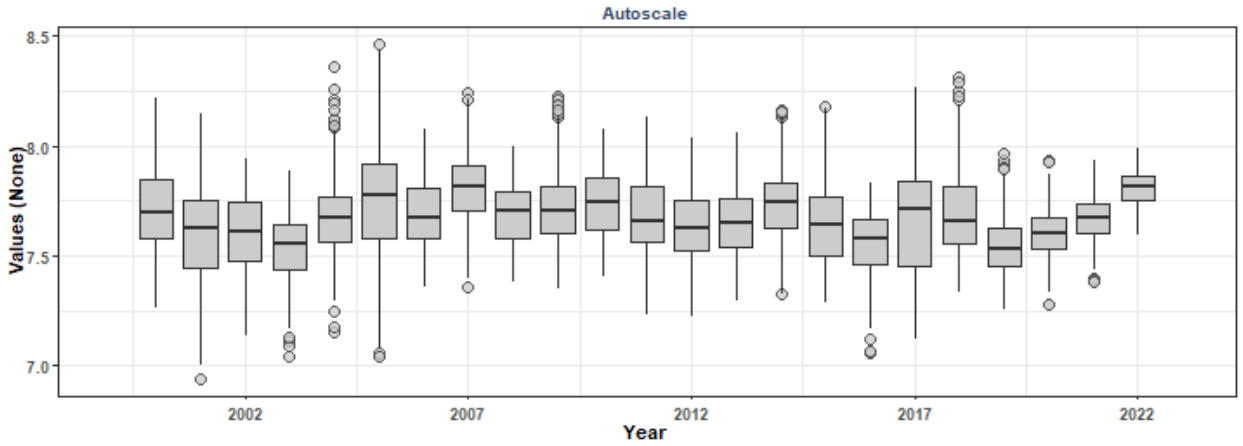


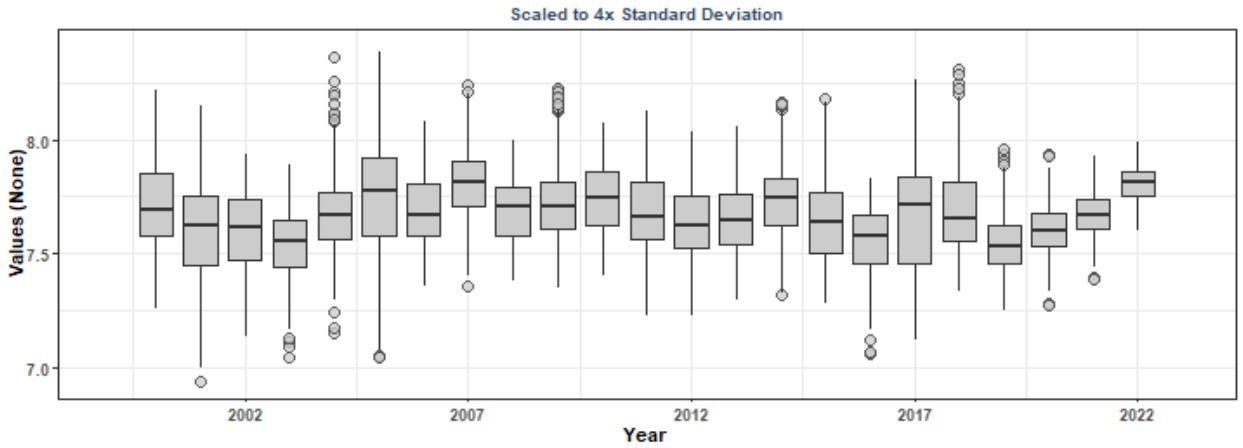

Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfuwq
By Year & Month
Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (None)
8.5
8.0
7.5
7.0
2002
2007
2012
2017
2022
Year
Scaled to 4x Standard Deviation
Values (None)
8.0
7.5
7.0
2002
2007
2012
2017
2022
Year
Scaled to 4x Standard Deviation, Last 10 Years
Values (None)
8.0
7.5
7.0
2012
2014
2016
2018
2020
2022
Year

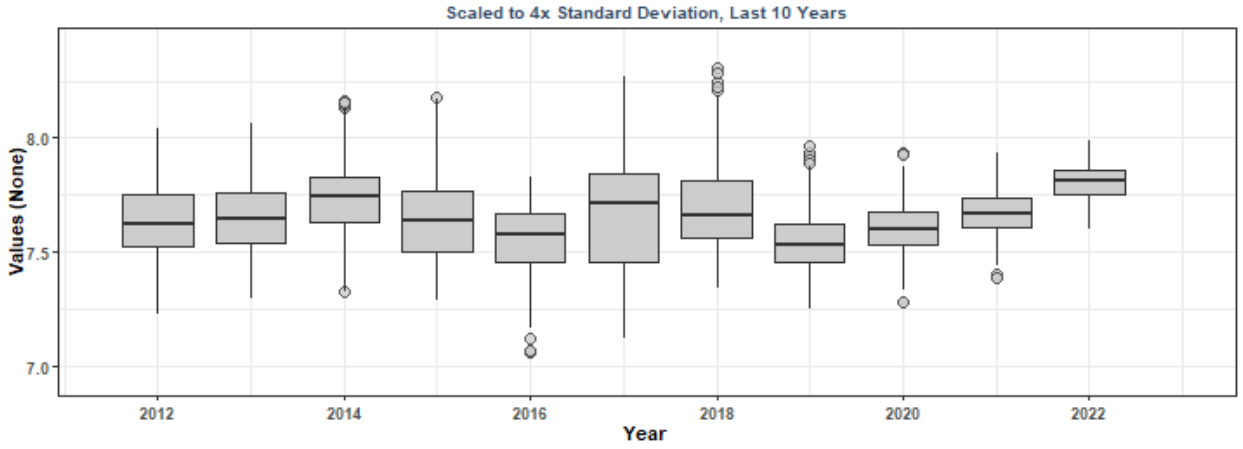
Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfuwq
By Month

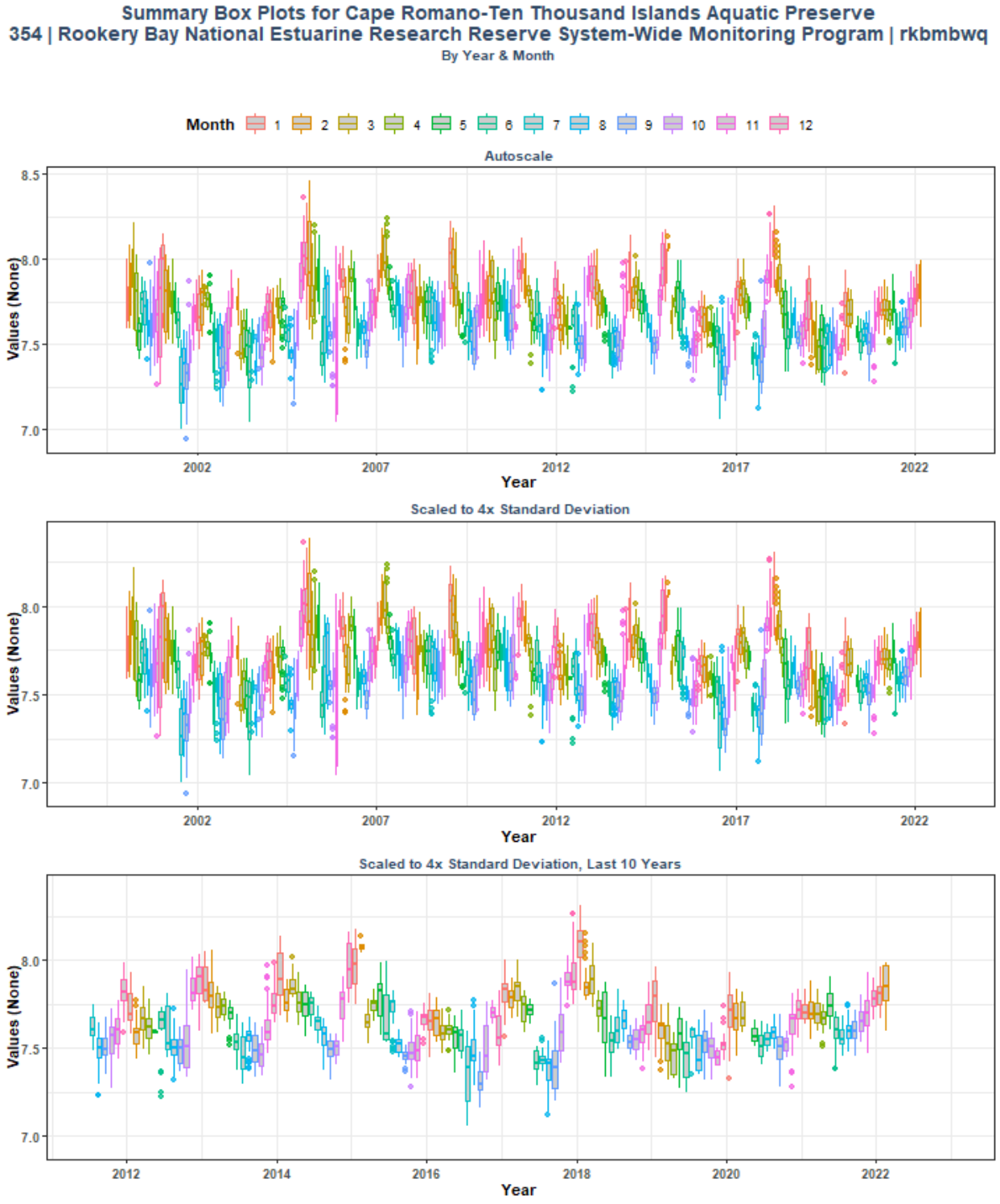


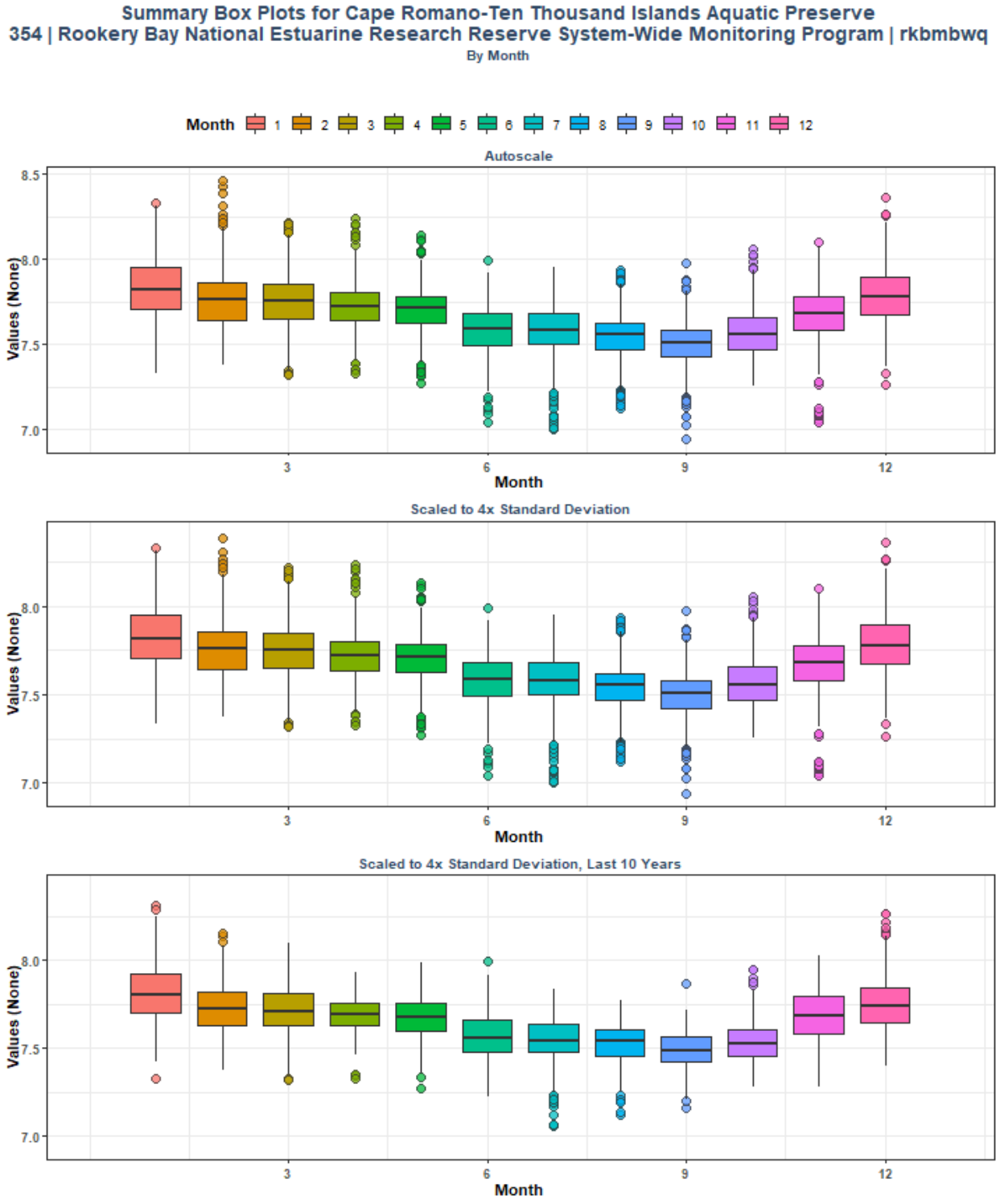
Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbmbwq
By Year



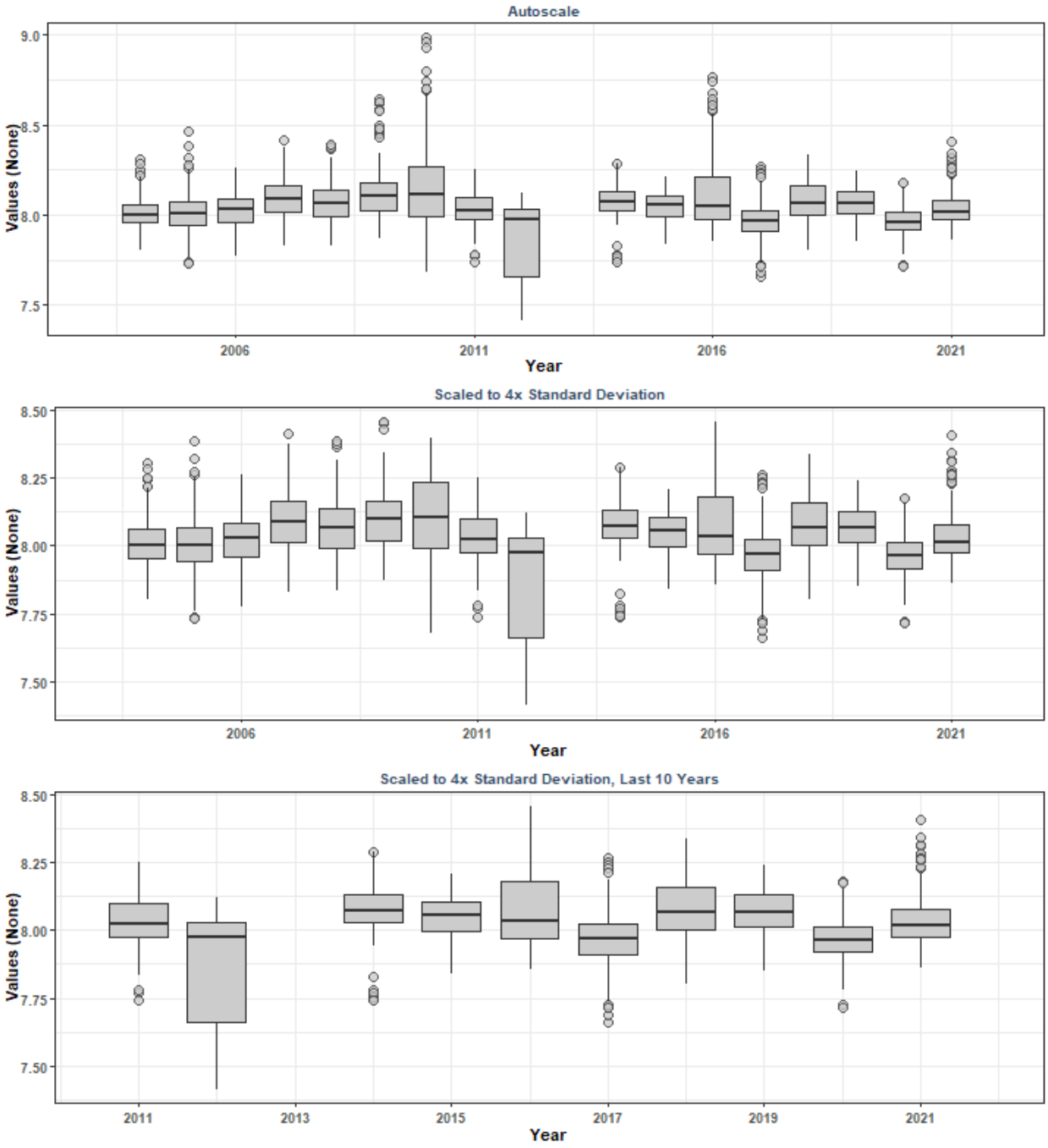


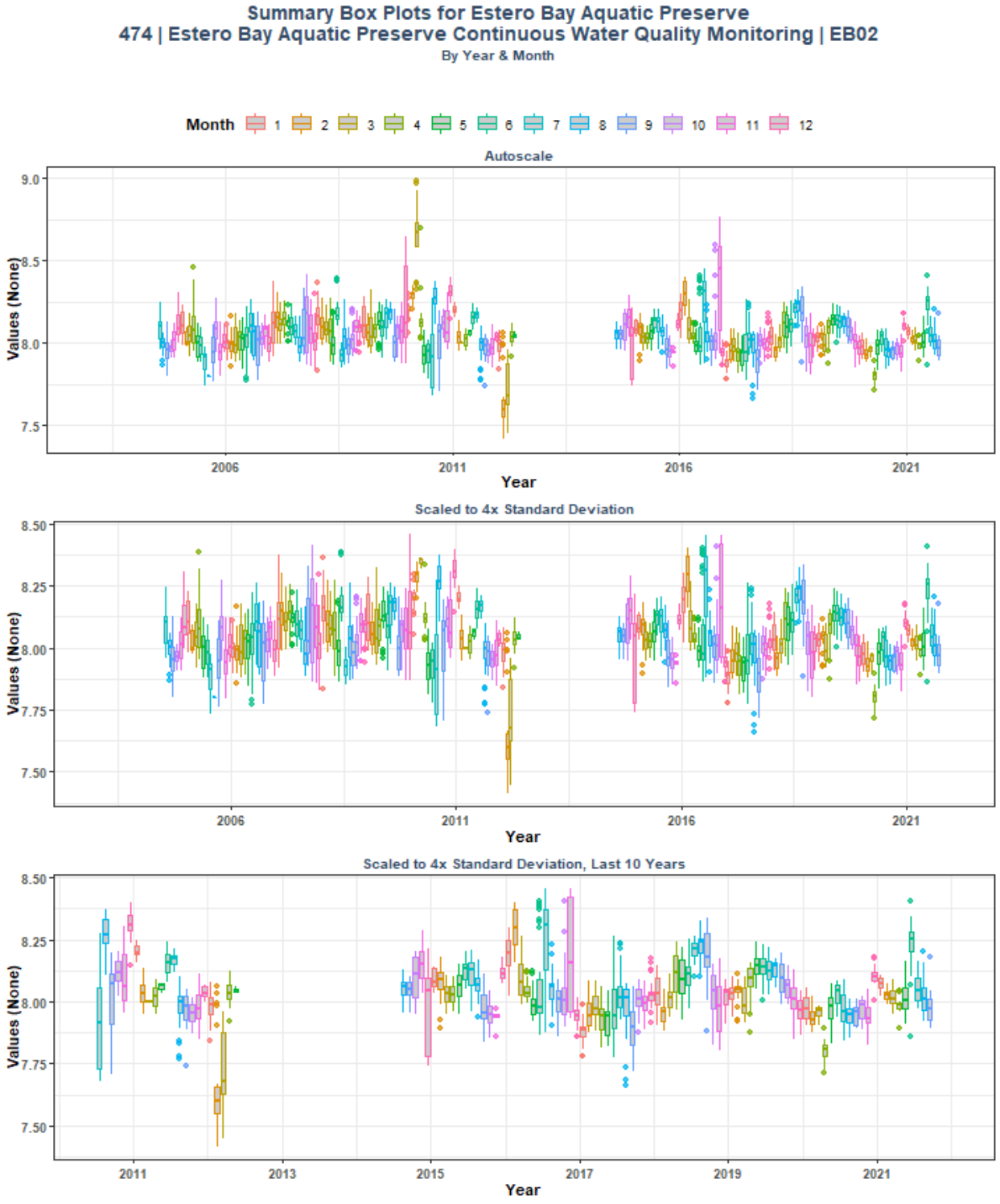


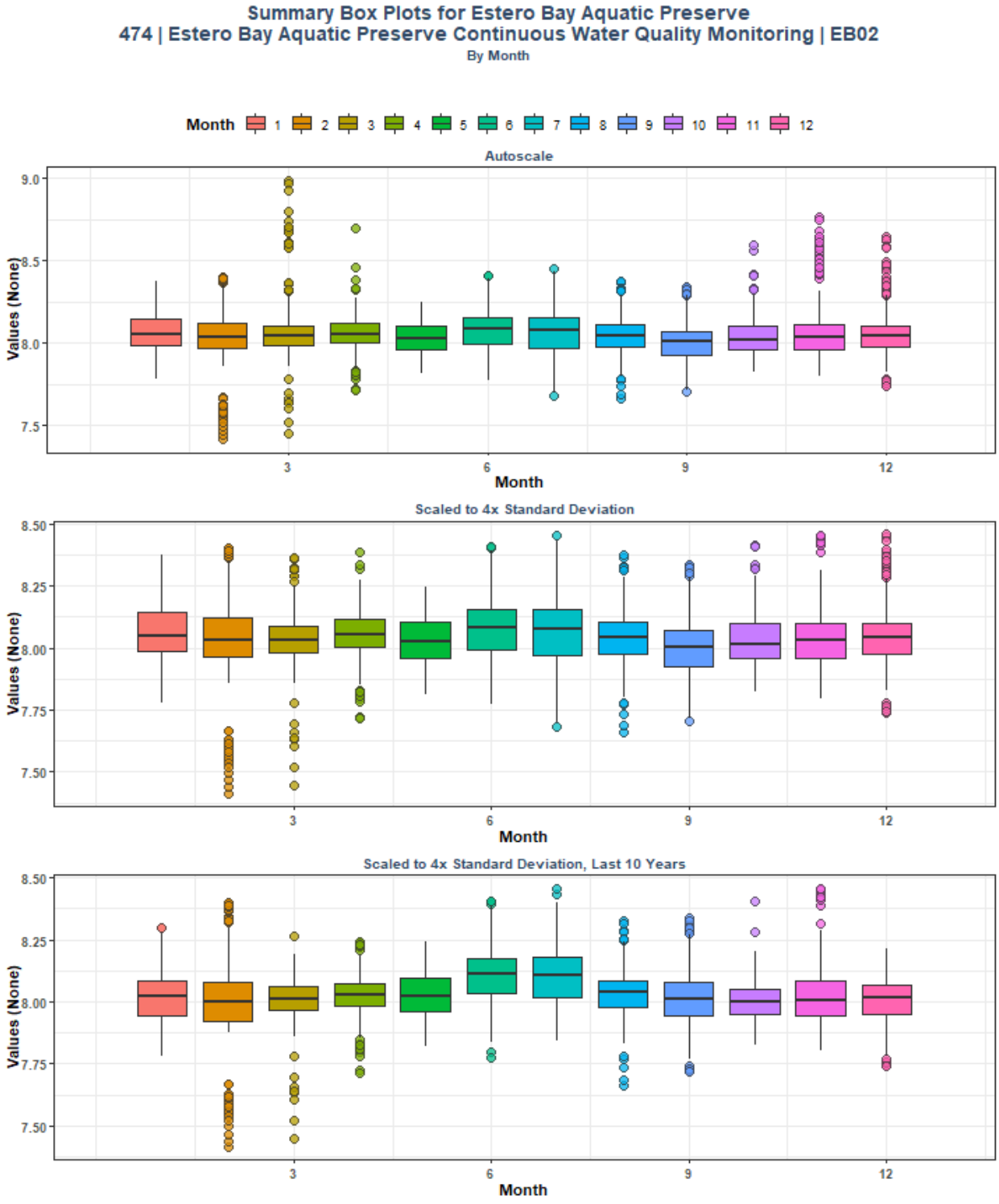

Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbmbwq
By Year & Month
Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (None)
Year
Scaled to 4x Standard Deviation
Values (None)
Year
Scaled to 4x Standard Deviation, Last 10 Years
Values (None)
Year


Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbmbwq
By Month
Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (None)
8.5
8.0
7.5
7.0
3
6
9
12
Month
Scaled to 4x Standard Deviation
Values (None)
8.0
7.5
7.0
3
6
9
12
Month
Scaled to 4x Standard Deviation, Last 10 Years
Values (None)
8.0
7.5
7.0
3
6
9
12
Month

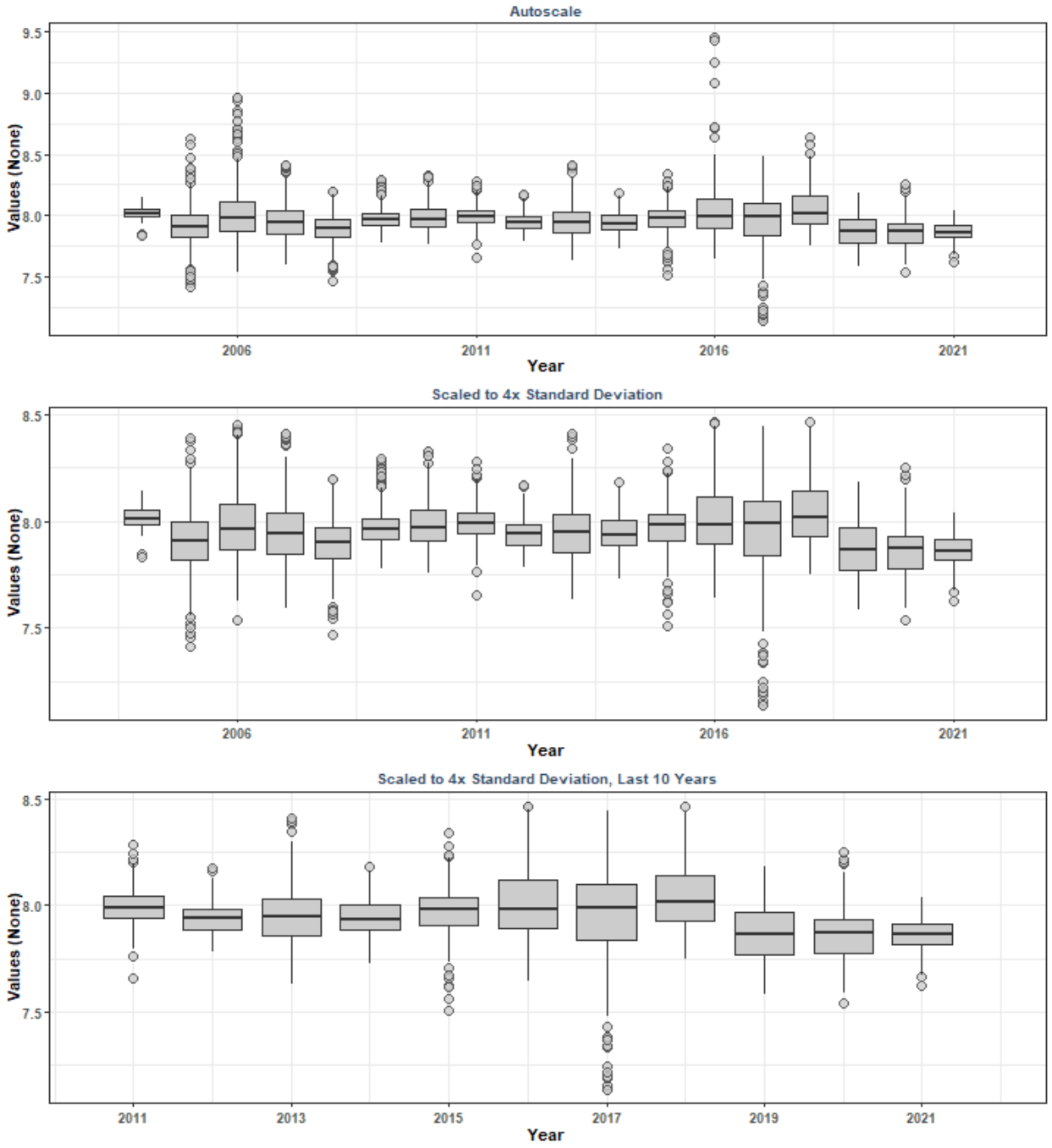
Summary Box Plots for Estero Bay Aquatic Preserve
474 | Estero Bay Aquatic Preserve Continuous Water Quality Monitoring | EB02
By Year

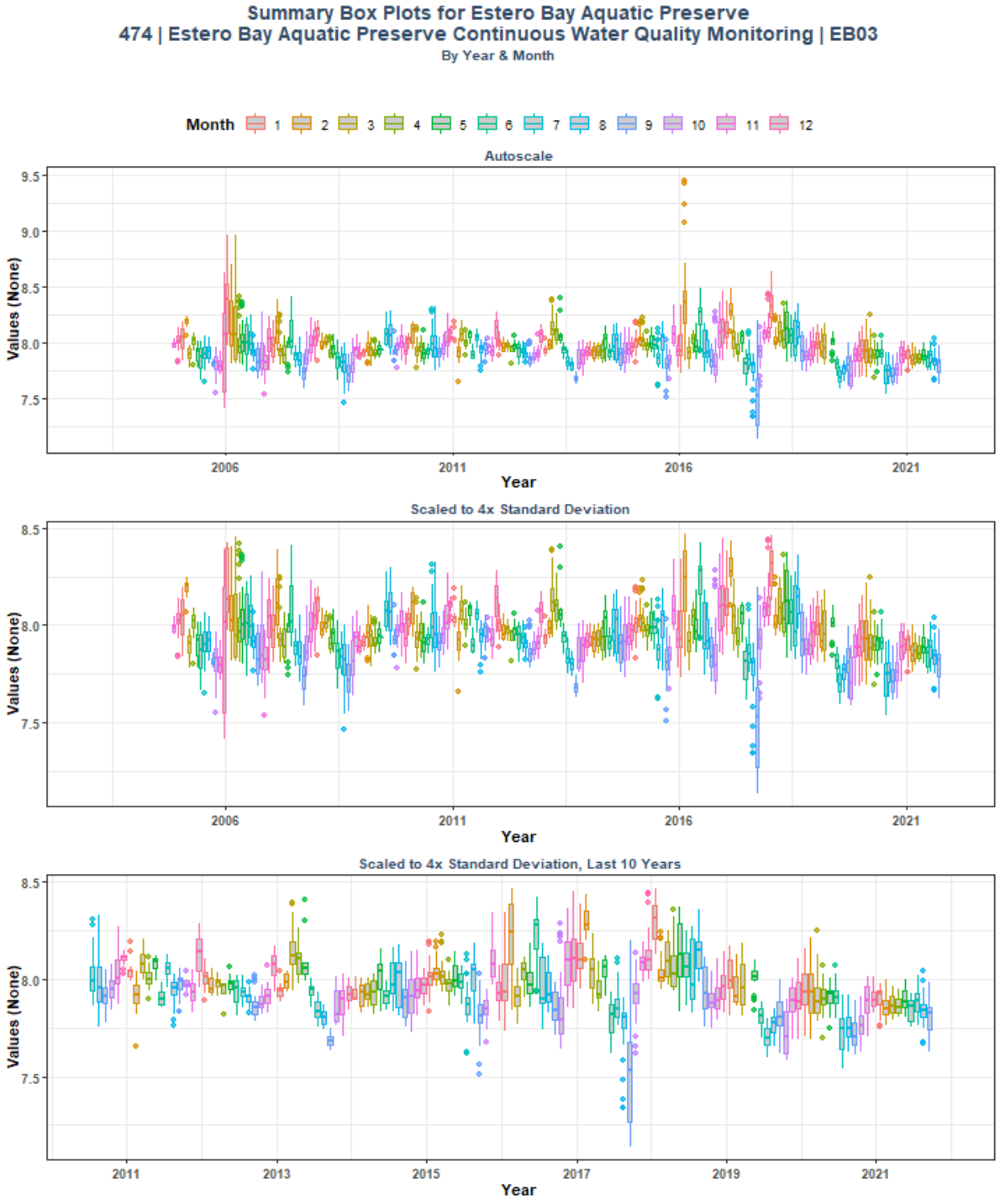



Summary Box Plots for Estero Bay Aquatic Preserve
474 | Estero Bay Aquatic Preserve Continuous Water Quality Monitoring | EB02
By Year & Month
Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (None)
9.0
8.5
8.0
7.5
2006
2011
2016
2021
Year
Scaled to 4x Standard Deviation
Values (None)
8.50
8.25
8.00
7.75
7.50
2006
2011
2016
2021
Year
Scaled to 4x Standard Deviation, Last 10 Years
Values (None)
8.50
8.25
8.00
7.75
7.50
2011
2013
2015
2017
2019
2021
Year

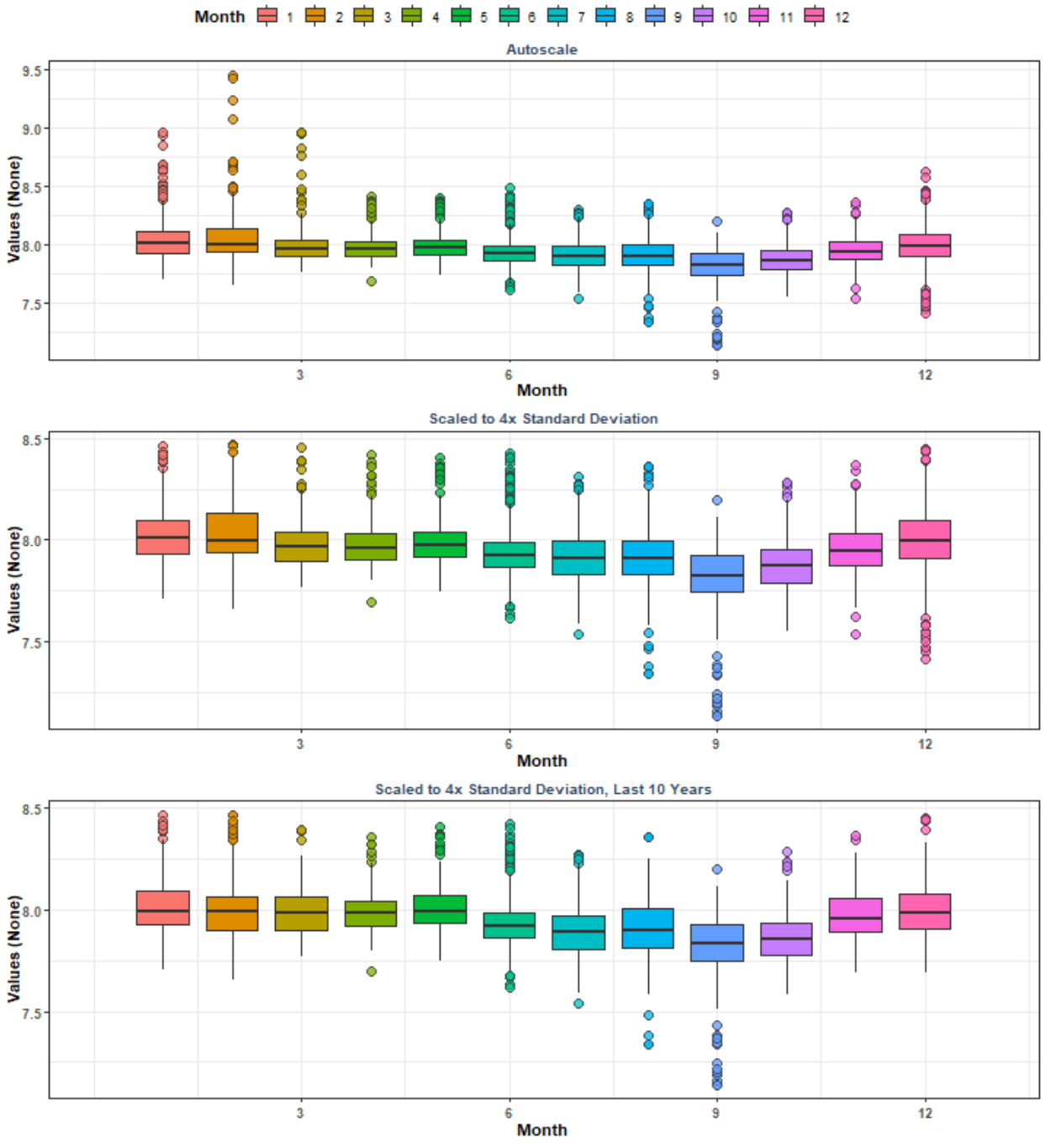

Summary Box Plots for Estero Bay Aquatic Preserve
474 | Estero Bay Aquatic Preserve Continuous Water Quality Monitoring | EB02
By Month
Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (None)
9.0
8.5
8.0
7.5
3
6
9
12
Month
Scaled to 4x Standard Deviation
Values (None)
8.50
8.25
8.00
7.75
7.50
3
6
9
12
Month
Scaled to 4x Standard Deviation, Last 10 Years
Values (None)
8.50
8.25
8.00
7.75
7.50
3
6
9
12
Month

Summary Box Plots for Estero Bay Aquatic Preserve
474 | Estero Bay Aquatic Preserve Continuous Water Quality Monitoring | EB03
By Year

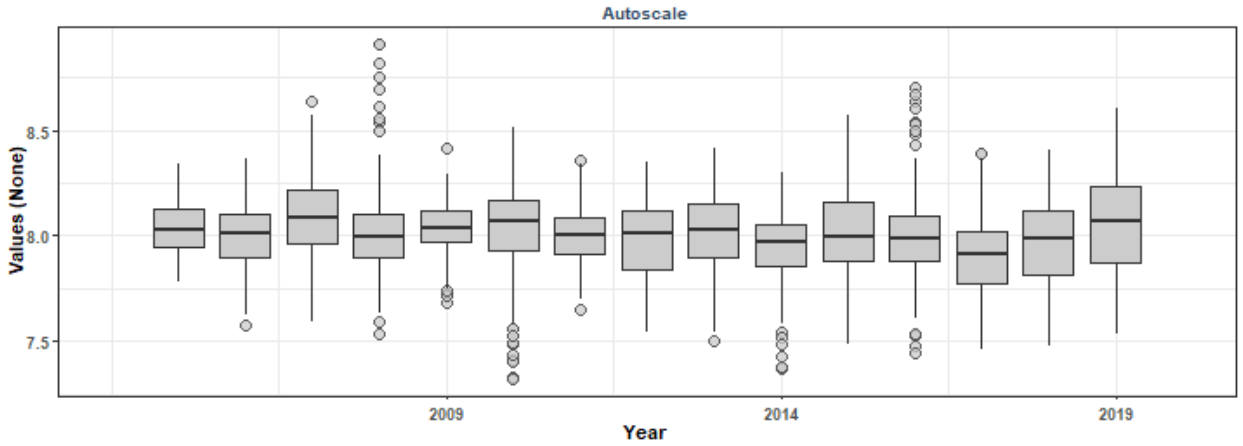


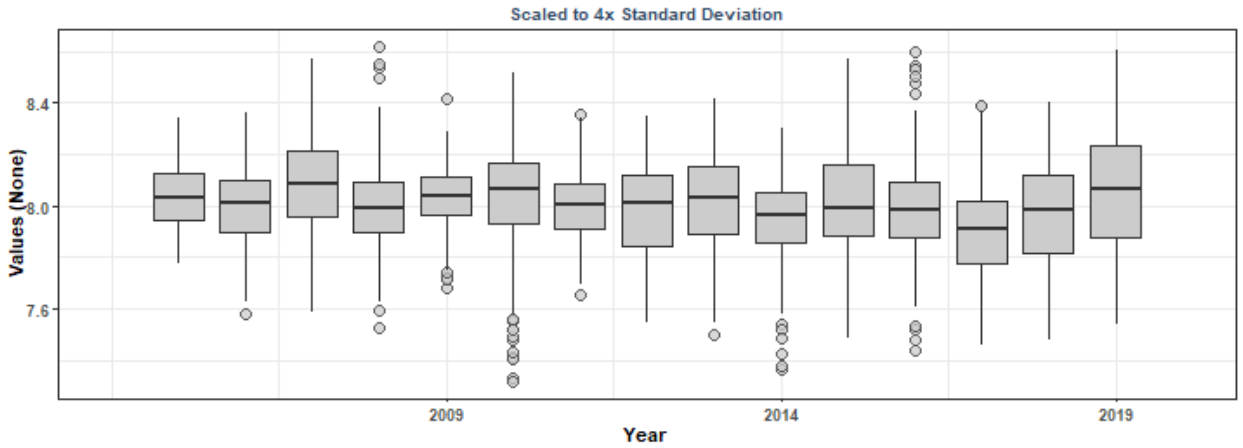

Summary Box Plots for Estero Bay Aquatic Preserve
474 | Estero Bay Aquatic Preserve Continuous Water Quality Monitoring | EB03
By Year & Month
Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (None)
9.5
9.0
8.5
8.0
7.5
2006
2011
2016
2021
Year
Scaled to 4x Standard Deviation
Values (None)
8.5
8.0
7.5
2006
2011
2016
2021
Year
Scaled to 4x Standard Deviation, Last 10 Years
Values (None)
8.5
8.0
7.5
2011
2013
2015
2017
2019
2021
Year

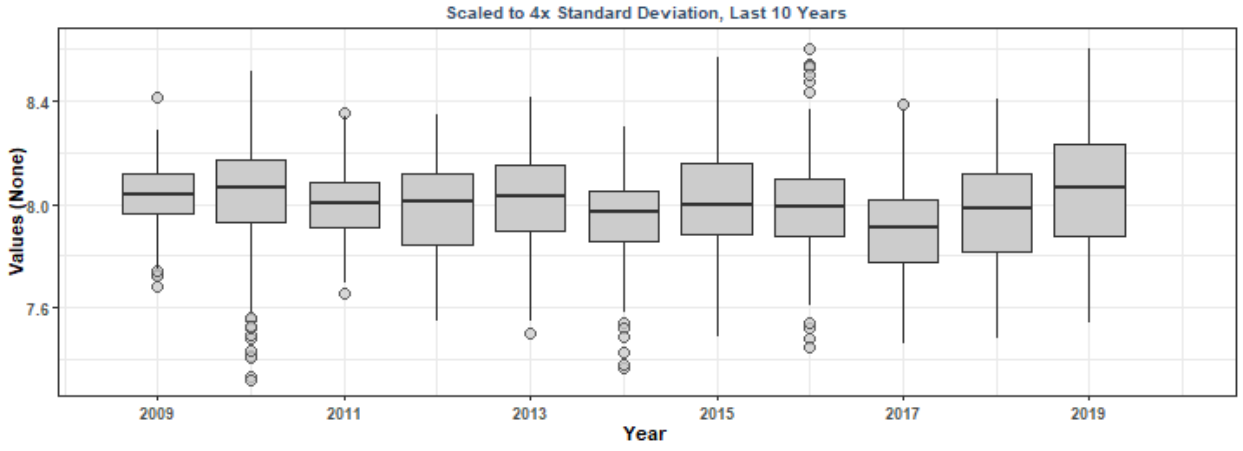
Summary Box Plots for Estero Bay Aquatic Preserve
474 | Estero Bay Aquatic Preserve Continuous Water Quality Monitoring | EB03
By Month



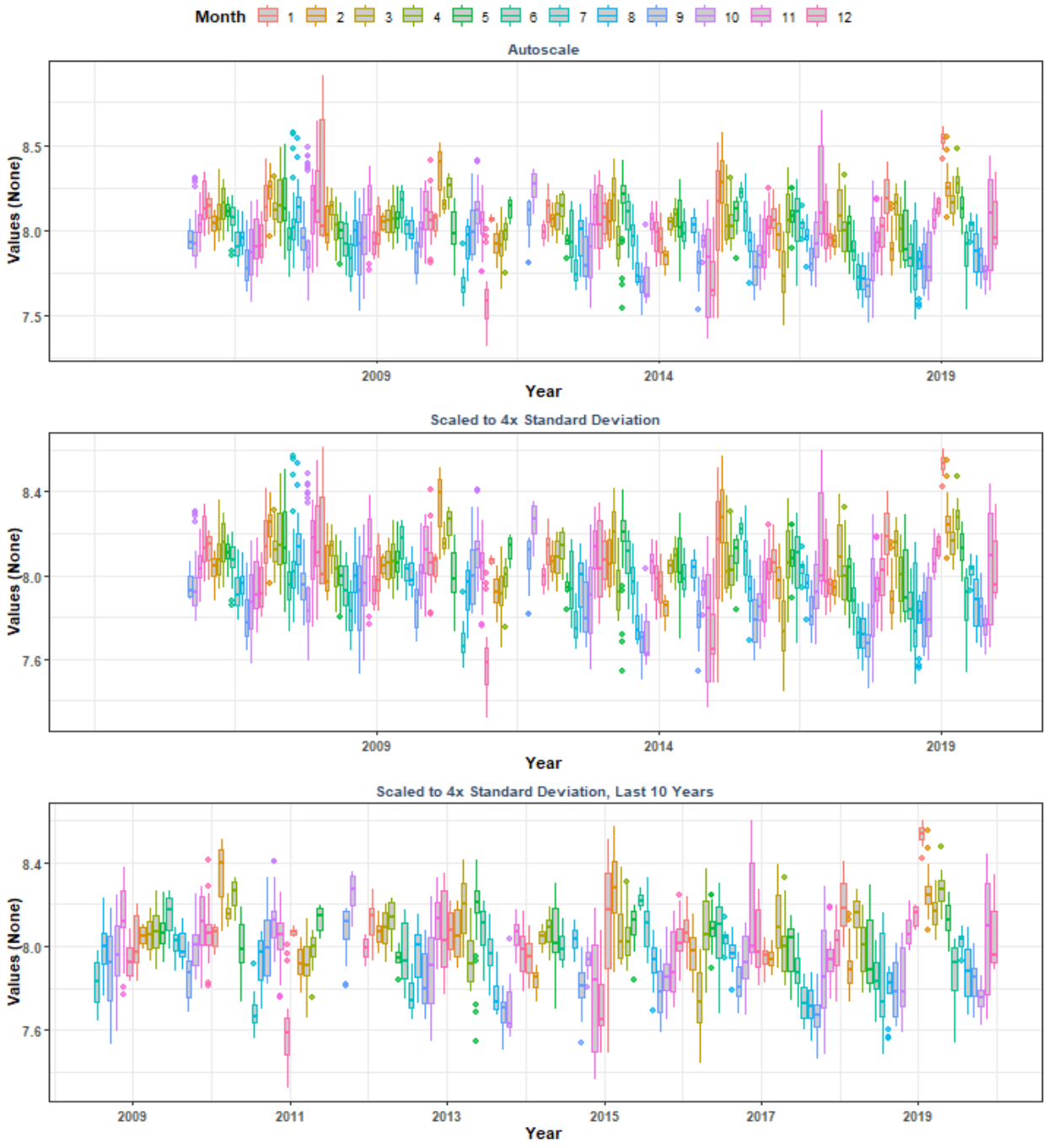
Summary Box Plots for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP1A
By Year

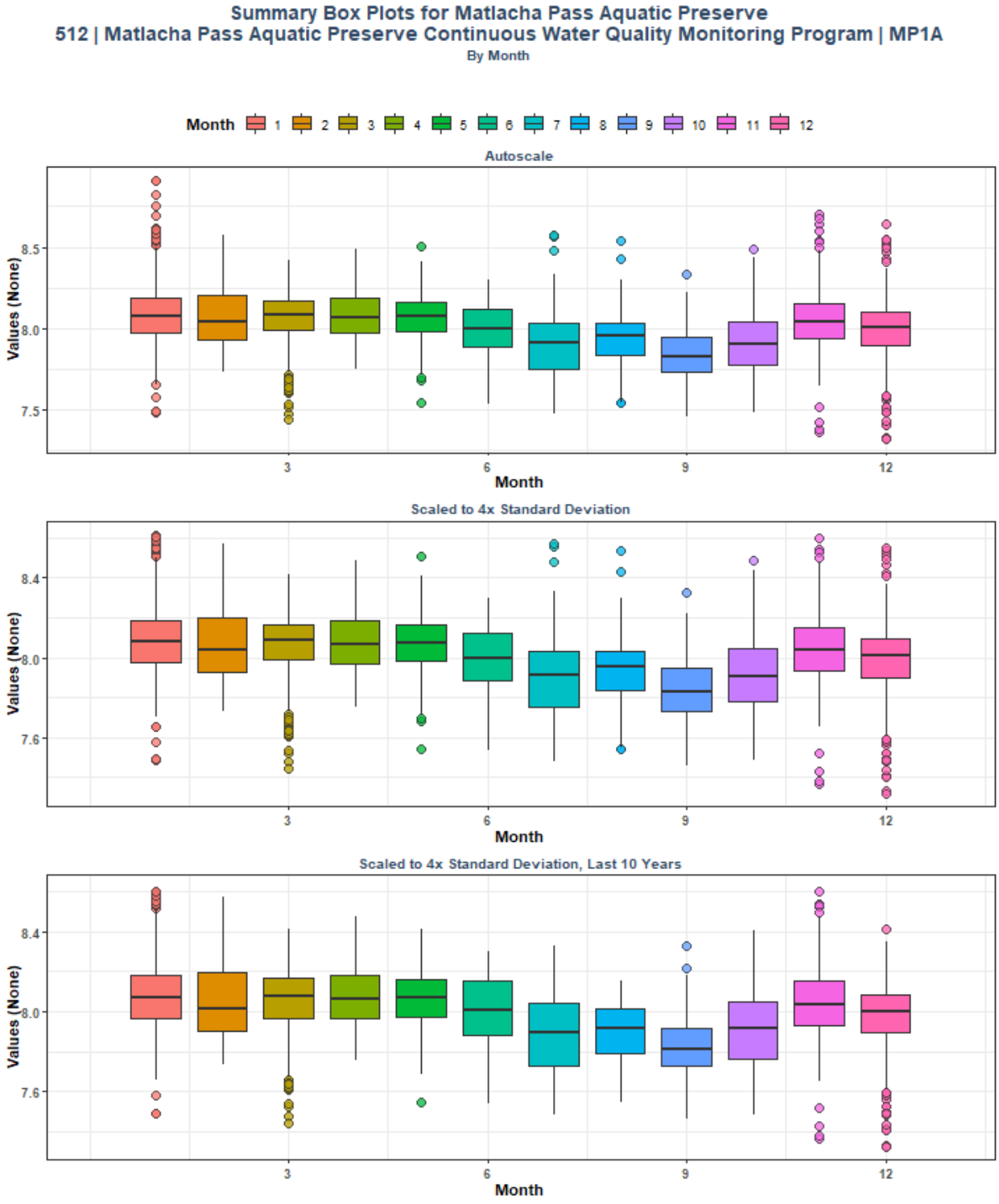




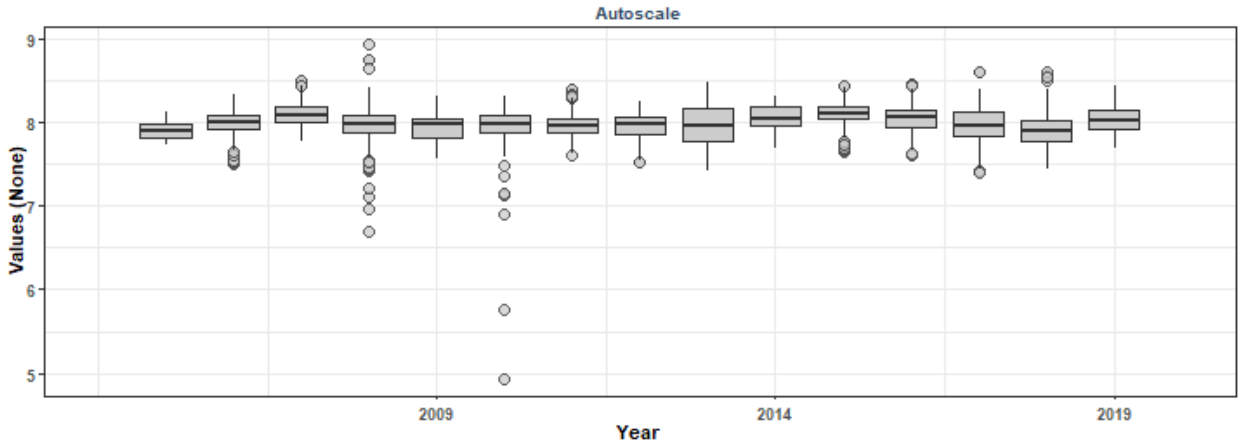


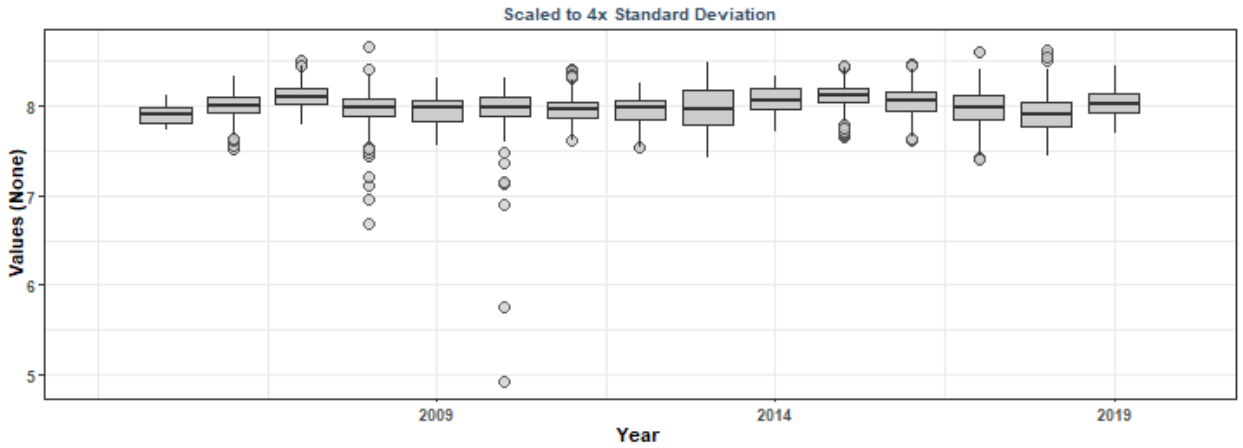
Summary Box Plots for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP1A
By Year & Month

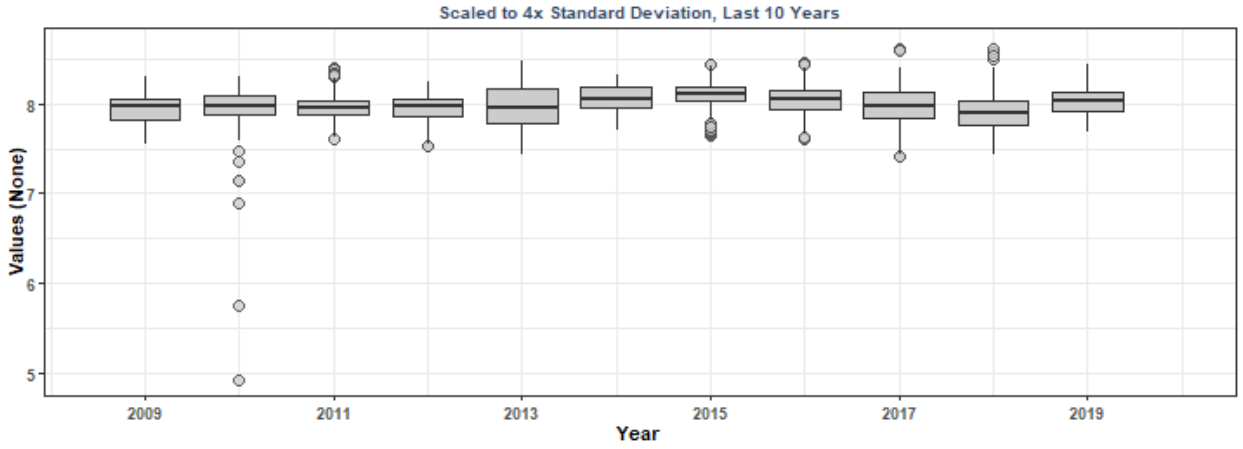



Summary Box Plots for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP1A
By Month
Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (None)
8.5
8.0
7.5
3
6
9
12
Month
Scaled to 4x Standard Deviation
Values (None)
8.4
8.0
7.6
3
6
9
12
Month
Scaled to 4x Standard Deviation, Last 10 Years
Values (None)
8.4
8.0
7.6
3
6
9
12
Month

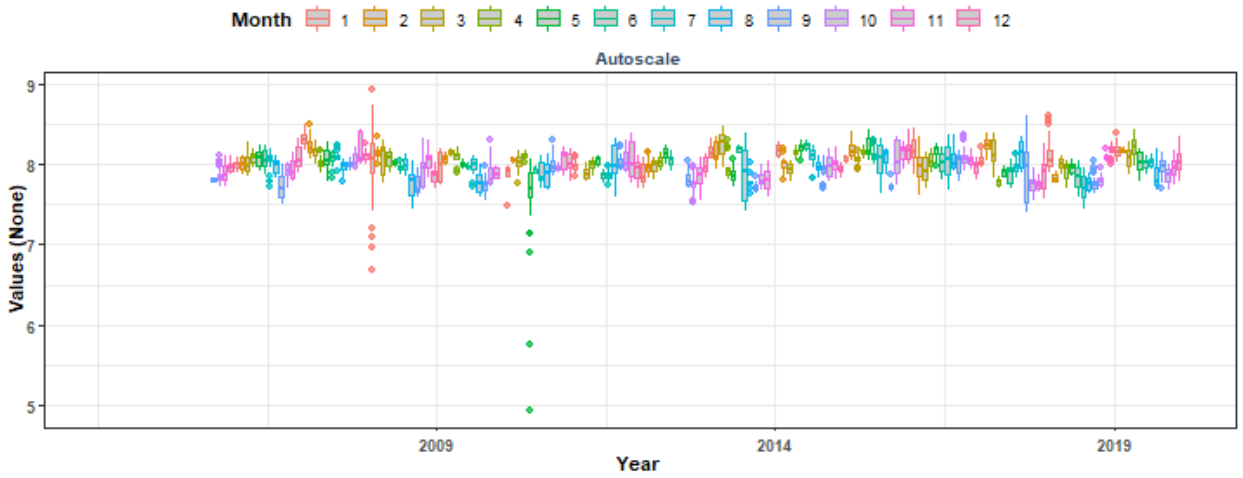
Summary Box Plots for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP2B
By Year

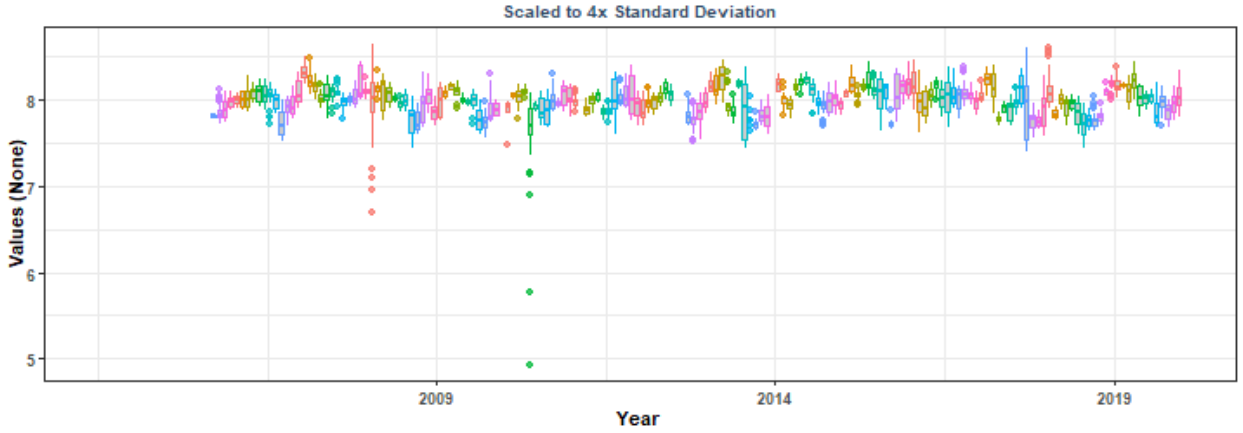


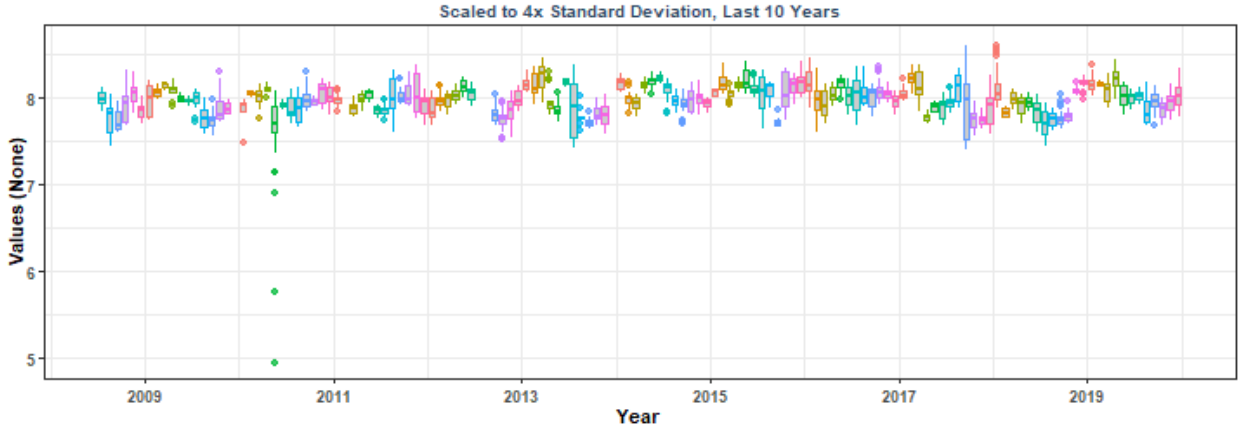




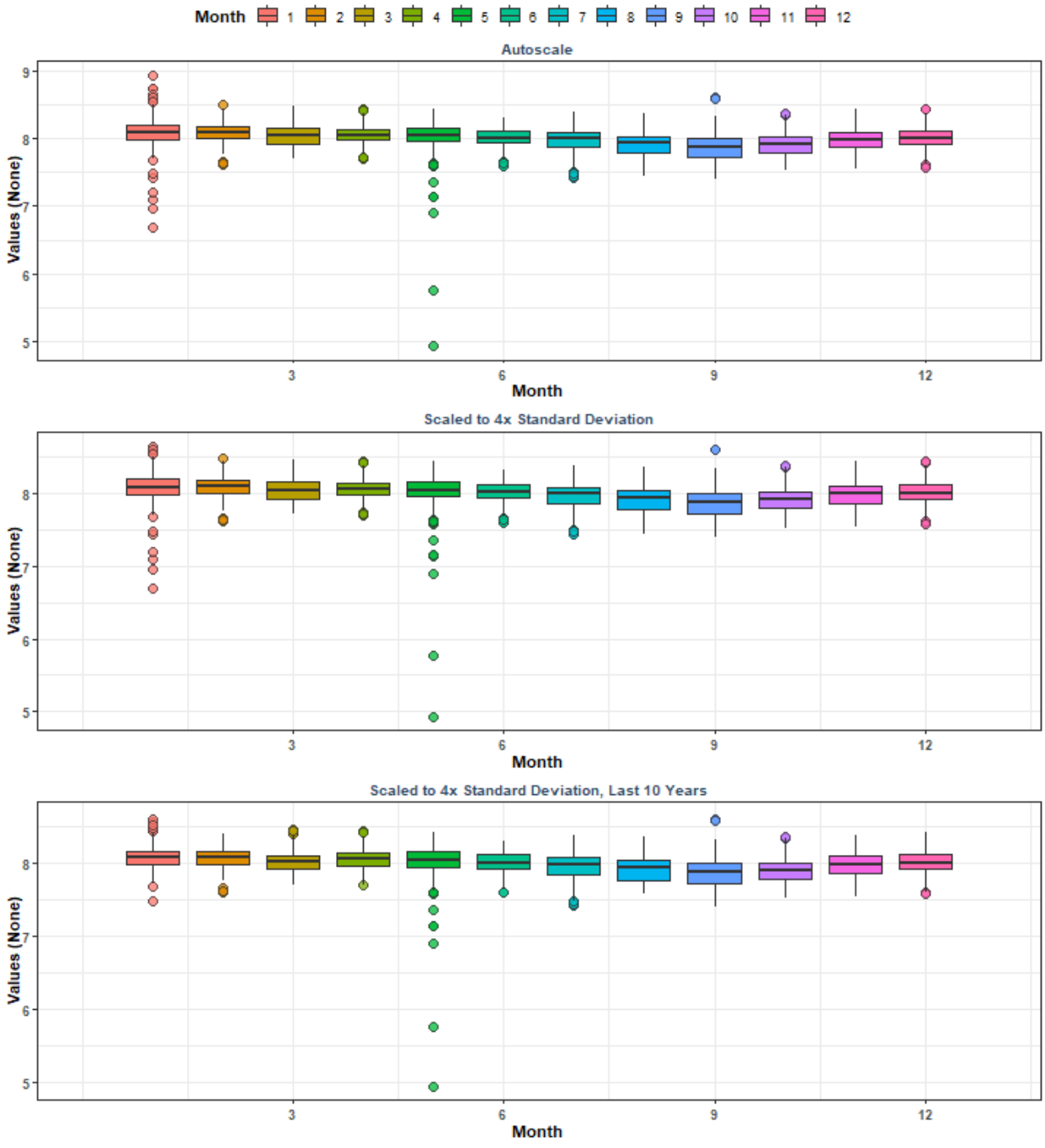
Summary Box Plots for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP2B
By Year & Month



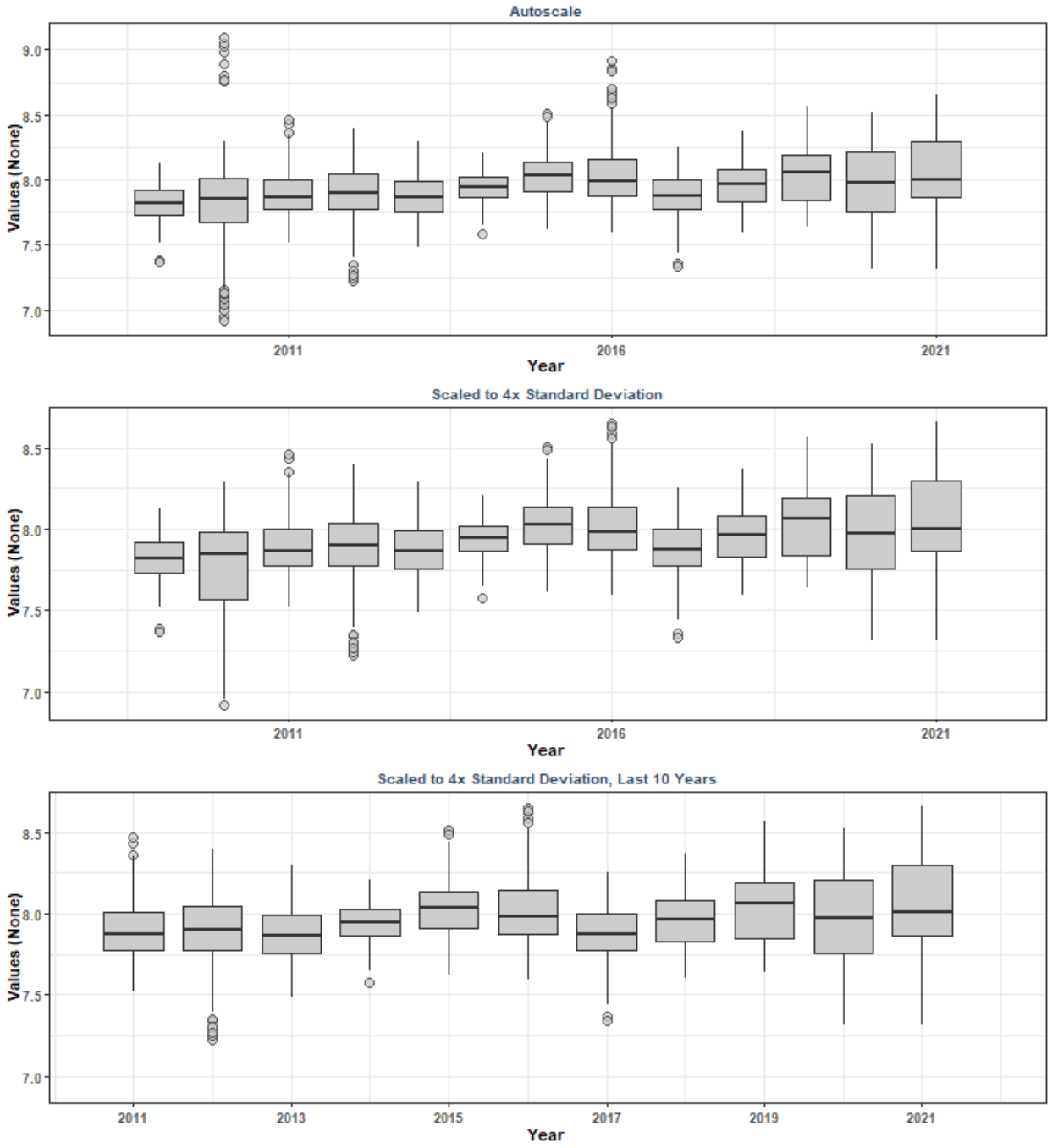


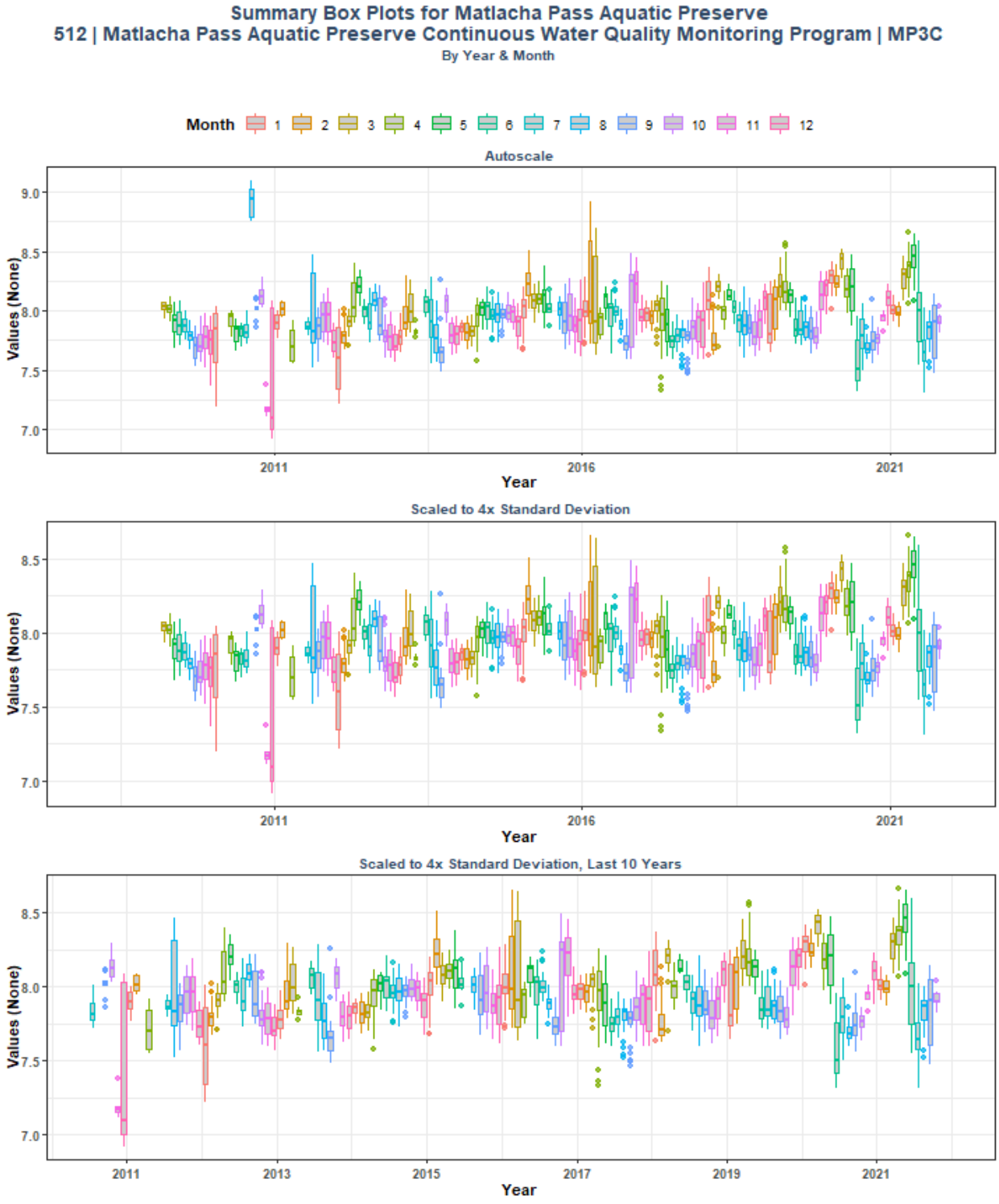


Summary Box Plots for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP2B
By Month

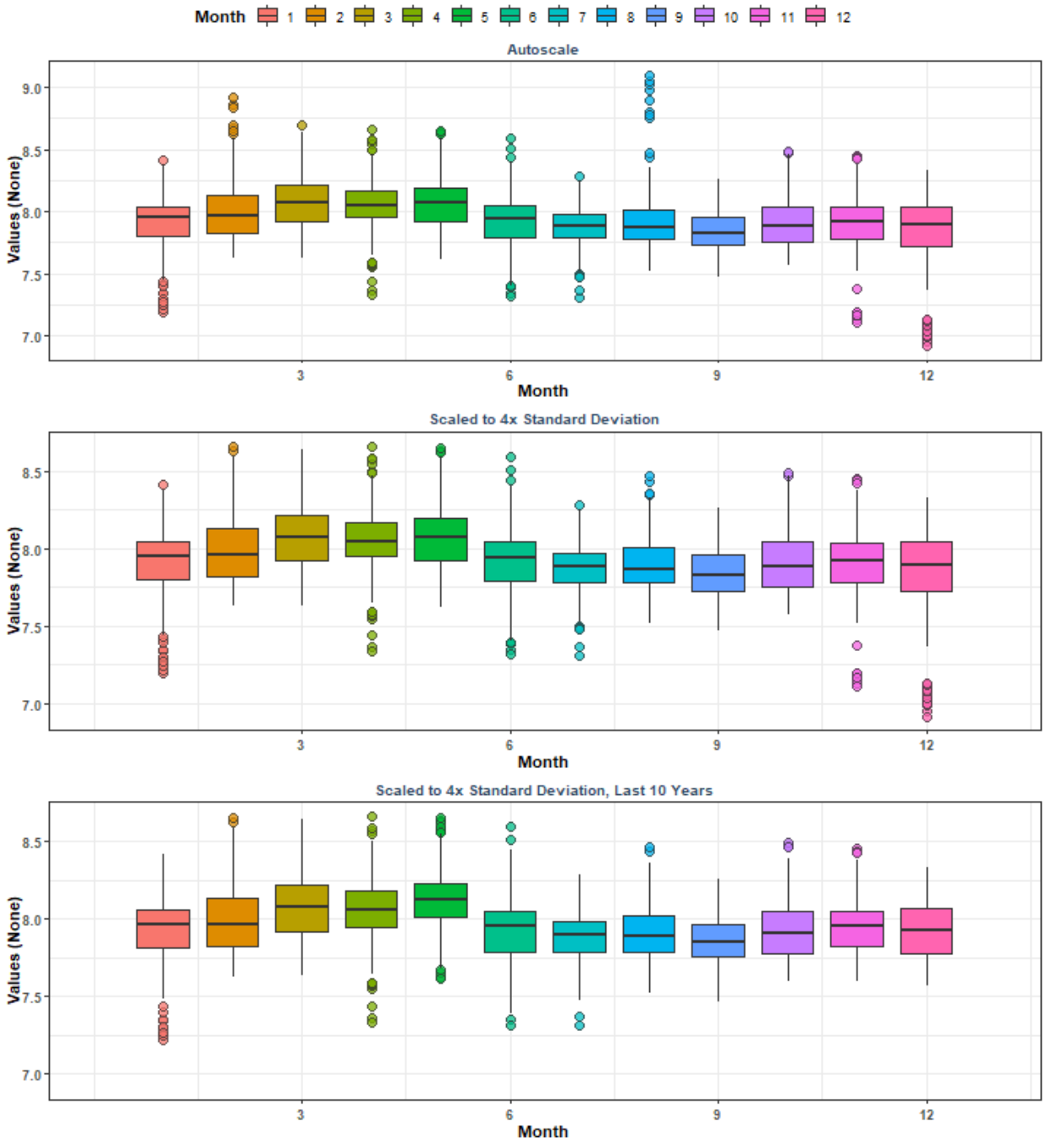


Summary Box Plots for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP3C
By Year

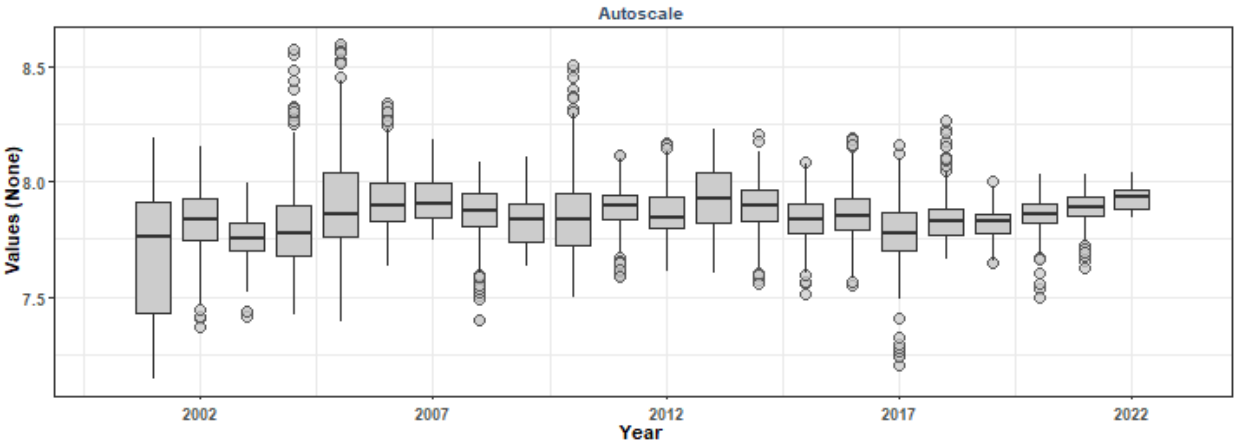


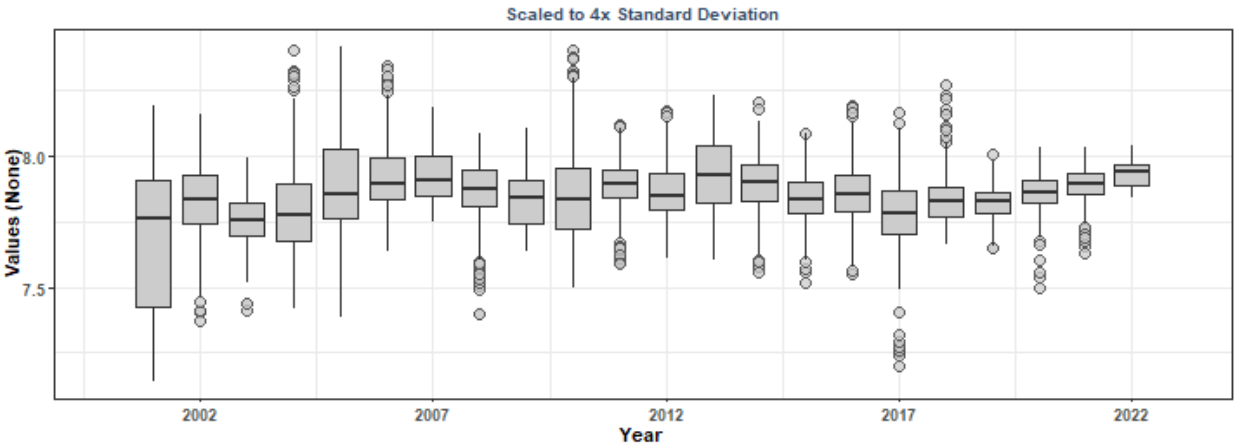

Summary Box Plots for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP3C
By Year & Month
Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (None)
9.0
8.5
8.0
7.5
7.0
2011
2016
2021
Year
Scaled to 4x Standard Deviation
Values (None)
8.5
8.0
7.5
7.0
2011
2016
2021
Year
Scaled to 4x Standard Deviation, Last 10 Years
Values (None)
8.5
8.0
7.5
7.0
2011
2013
2015
2017
2019
2021
Year

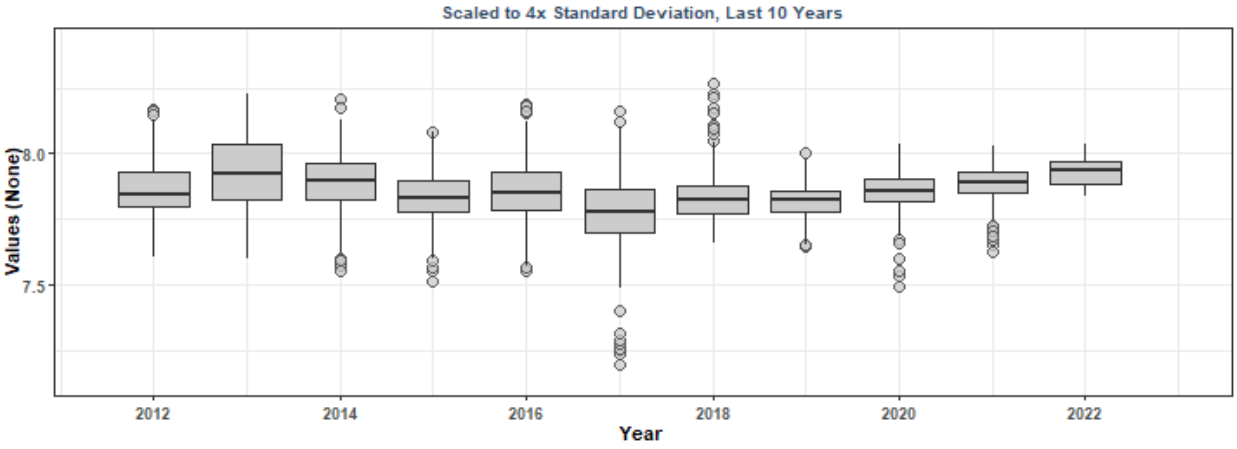
Summary Box Plots for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP3C
By Month

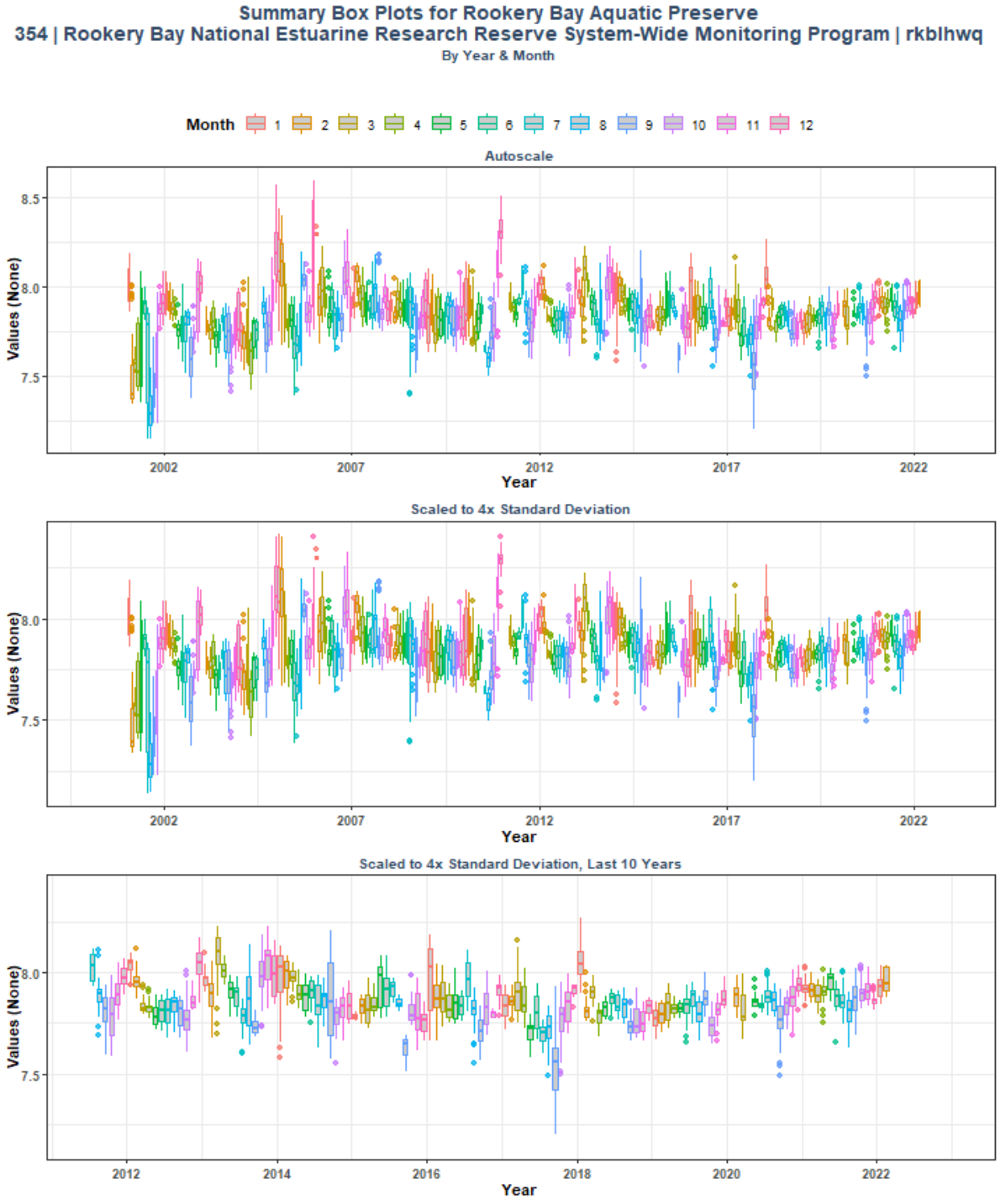


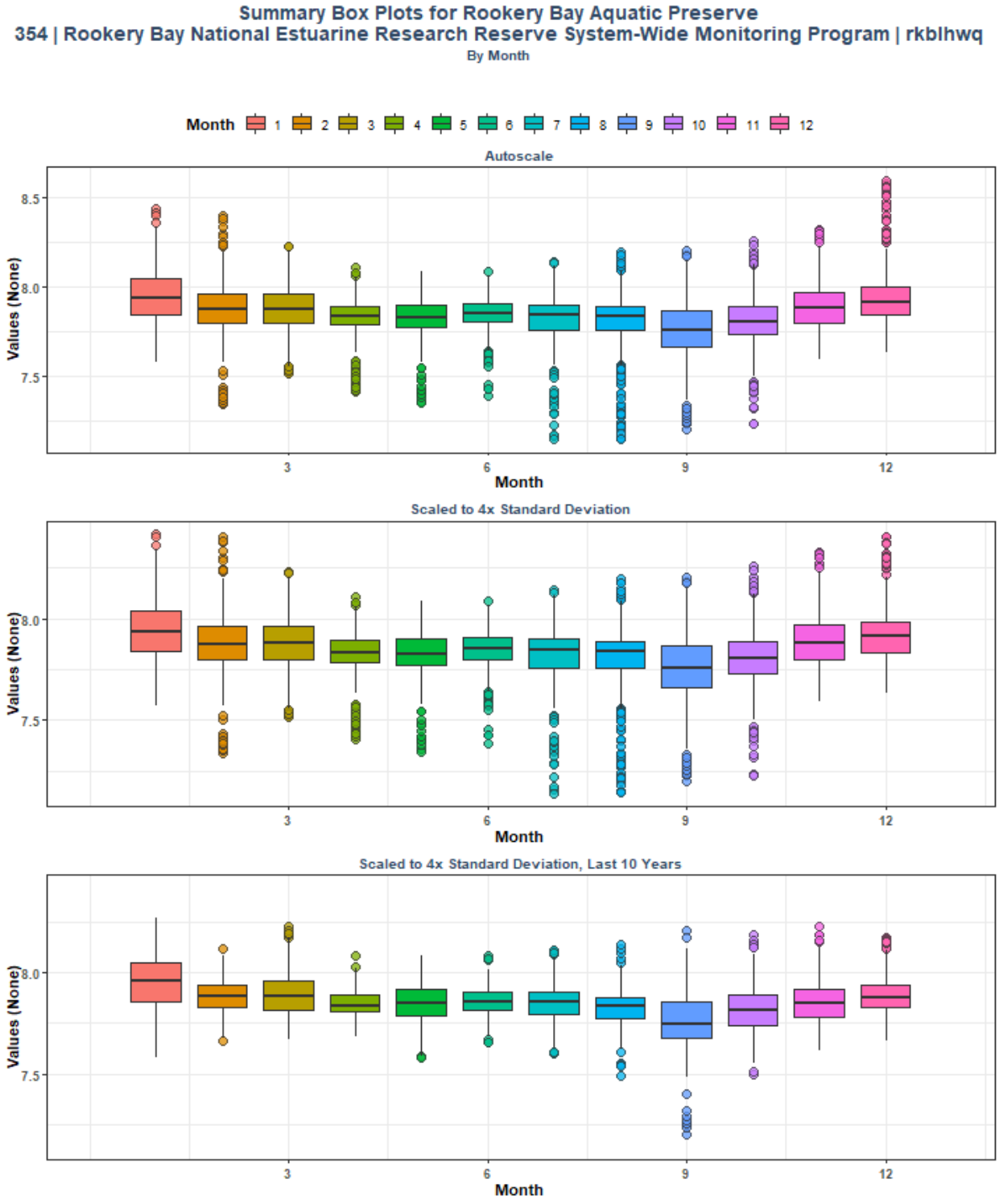
Summary Box Plots for Rookery Bay Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkblhwq
By Year





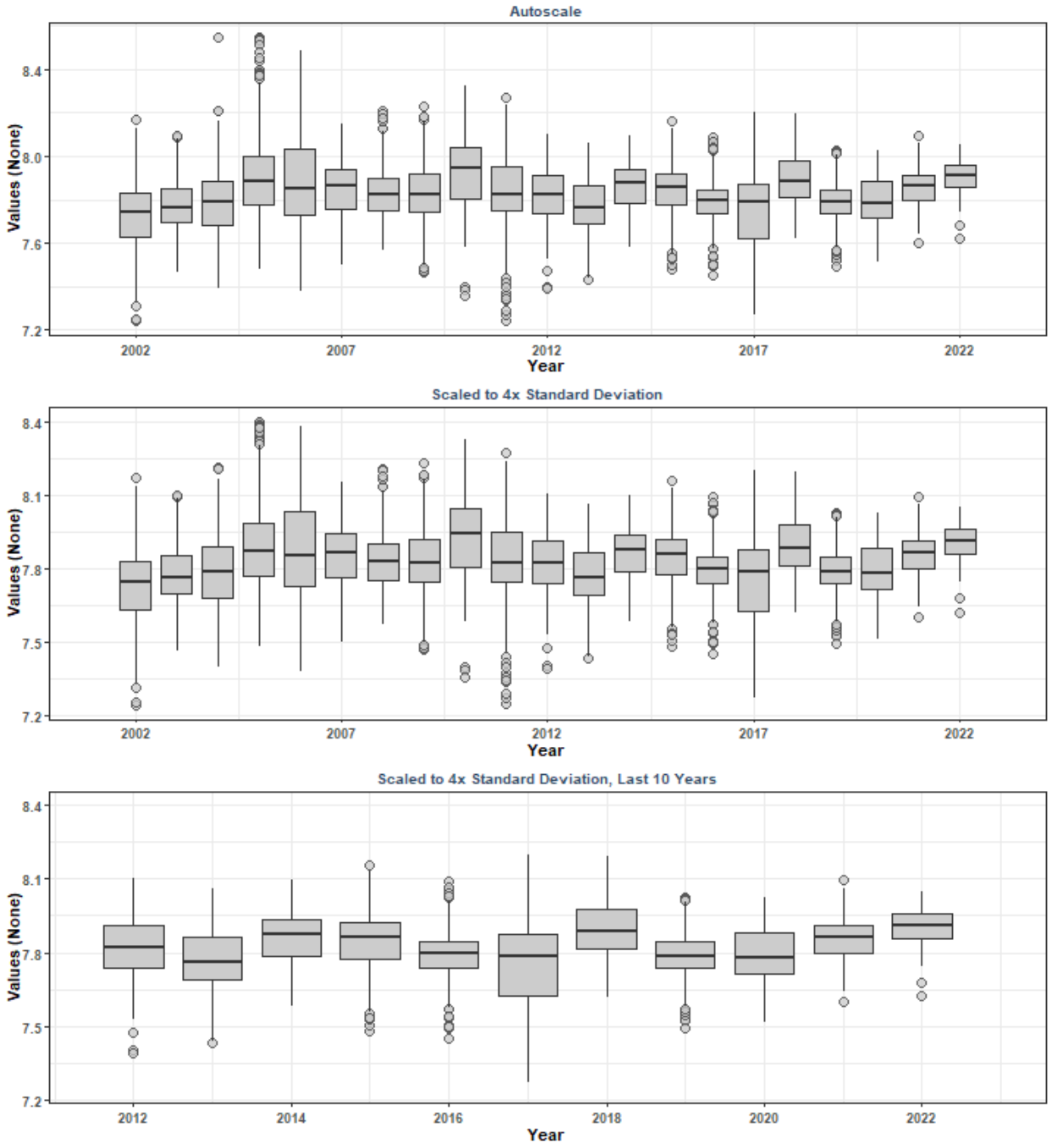


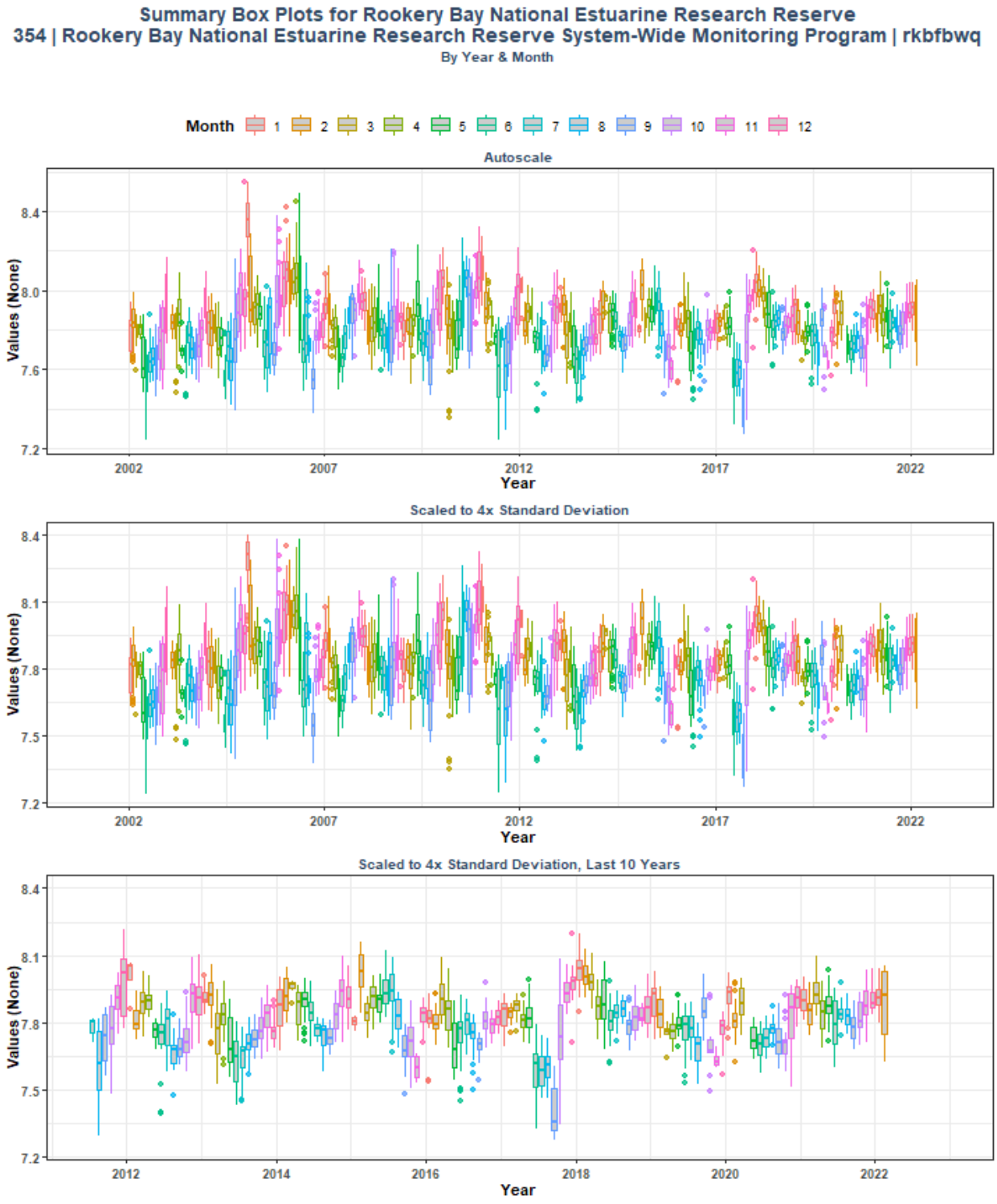

Summary Box Plots for Rookery Bay Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkblhwq
By Year & Month
Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (None)
8.5
8.0
7.5
2002
2007
2012
2017
2022
Year
Scaled to 4x Standard Deviation
Values (None)
8.0
7.5
2002
2007
2012
2017
2022
Year
Scaled to 4x Standard Deviation, Last 10 Years
Values (None)
8.0
7.5
2012
2014
2016
2018
2020
2022
Year


Summary Box Plots for Rookery Bay Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkblhwq
By Month
Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (None)
8.5
8.0
7.5
3
6
9
12
Month
Scaled to 4x Standard Deviation
Values (None)
8.0
7.5
3
6
9
12
Month
Scaled to 4x Standard Deviation, Last 10 Years
Values (None)
8.0
7.5
3
6
9
12
Month

Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfbwq

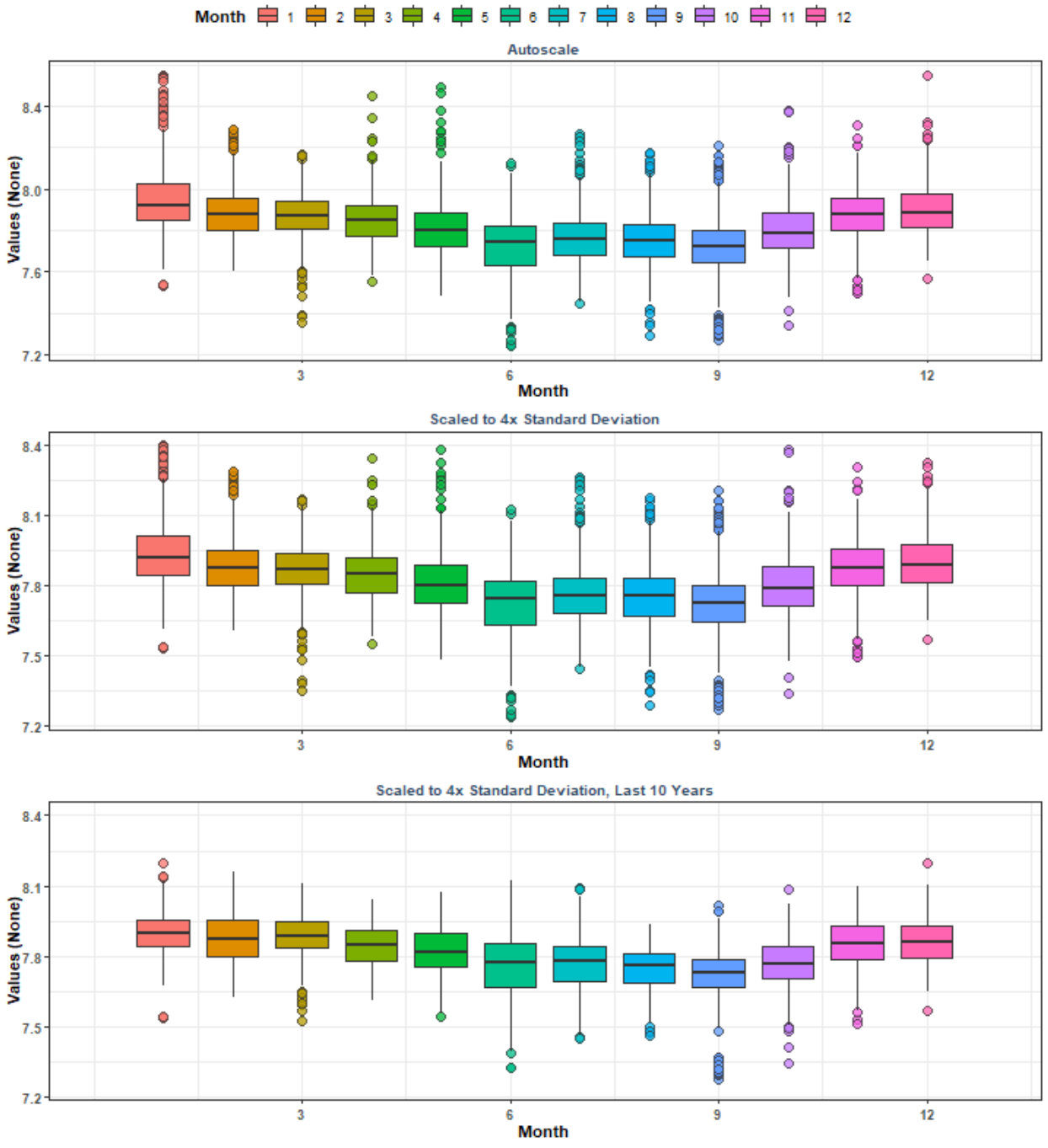
By Year




Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfbwq
By Year & Month
Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (None)
Year
Scaled to 4x Standard Deviation
Values (None)
Year
Scaled to 4x Standard Deviation, Last 10 Years
Values (None)
Year

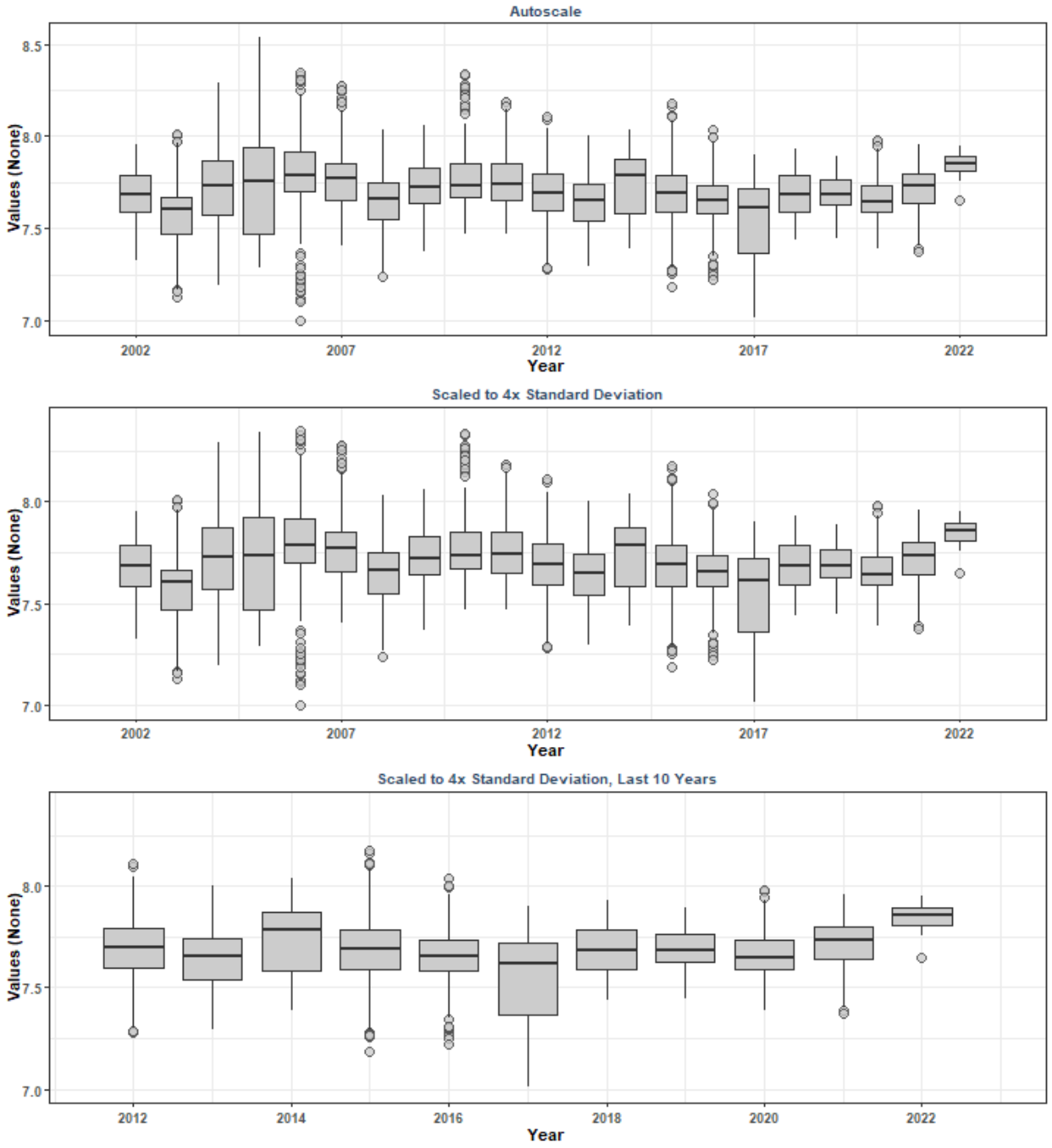
Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfbwq

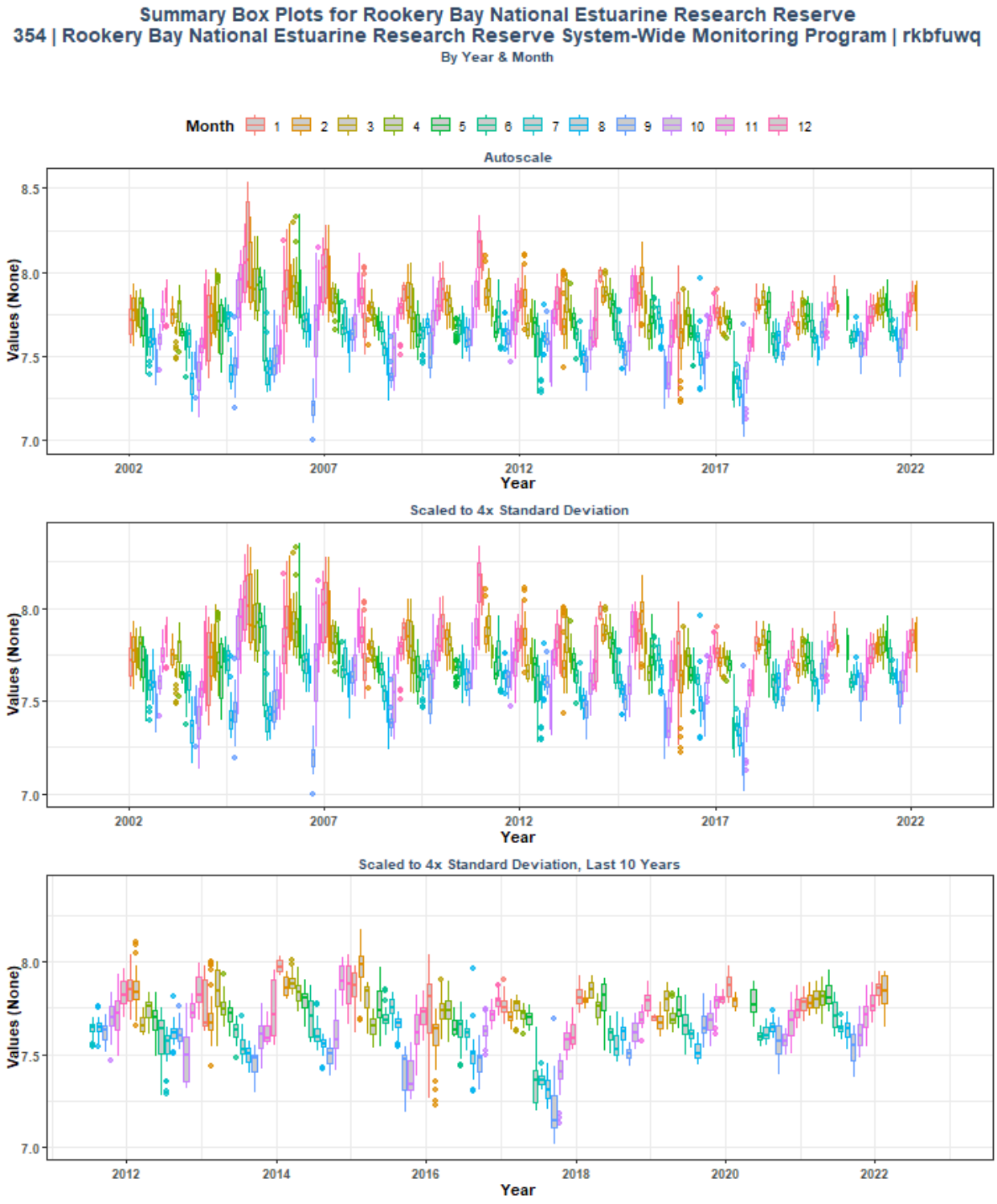
By Month

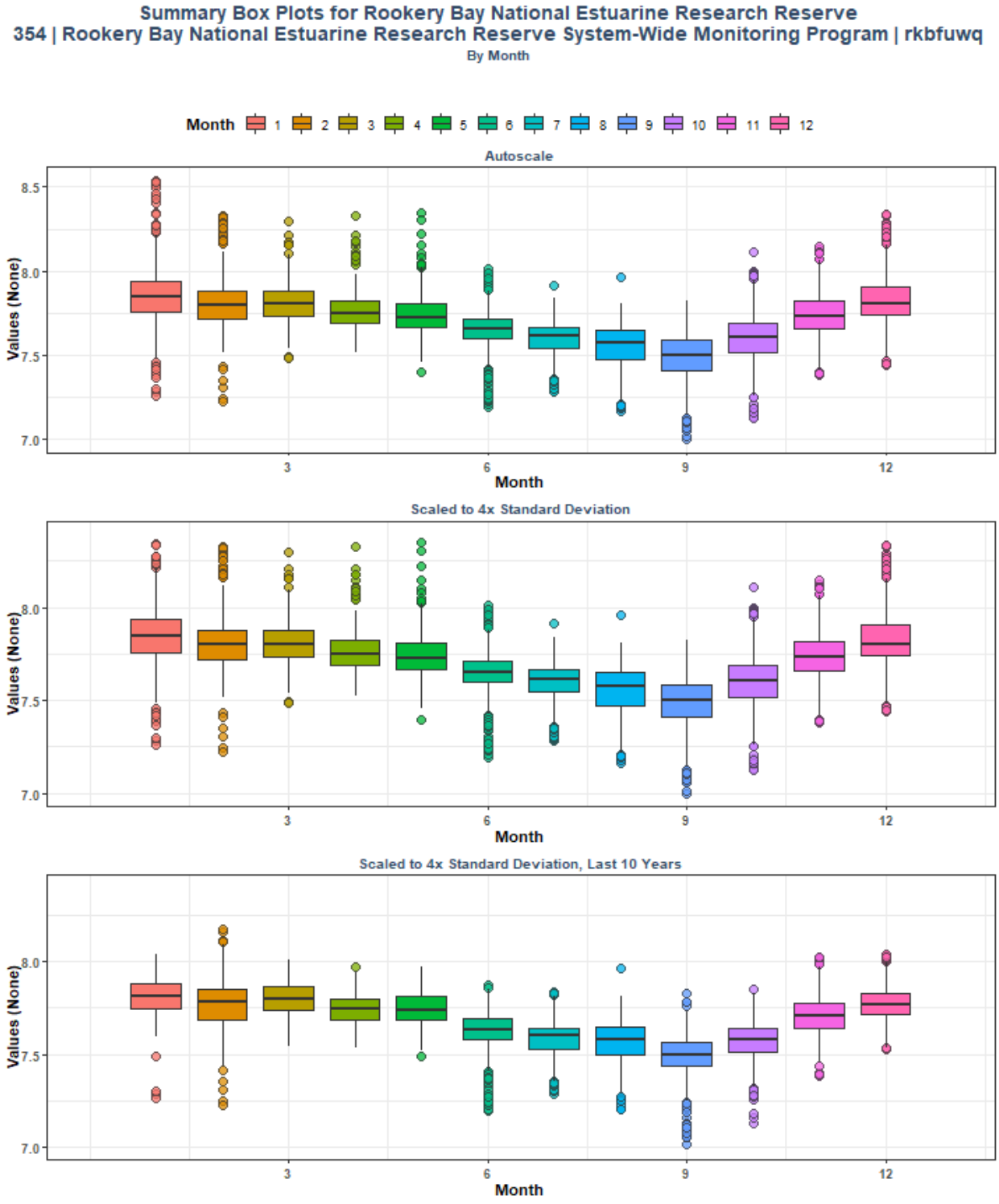


Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfuwq

By Year

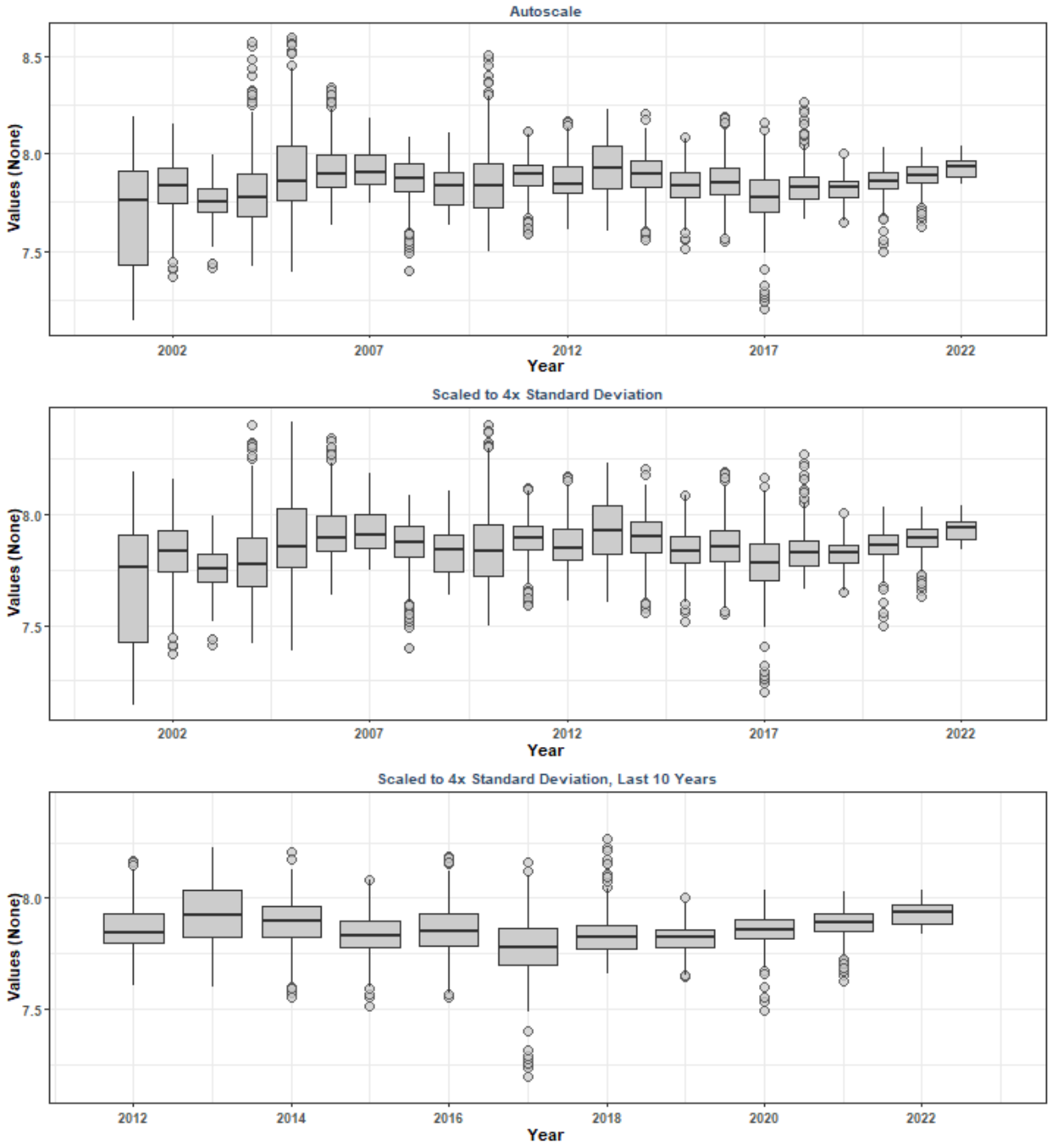


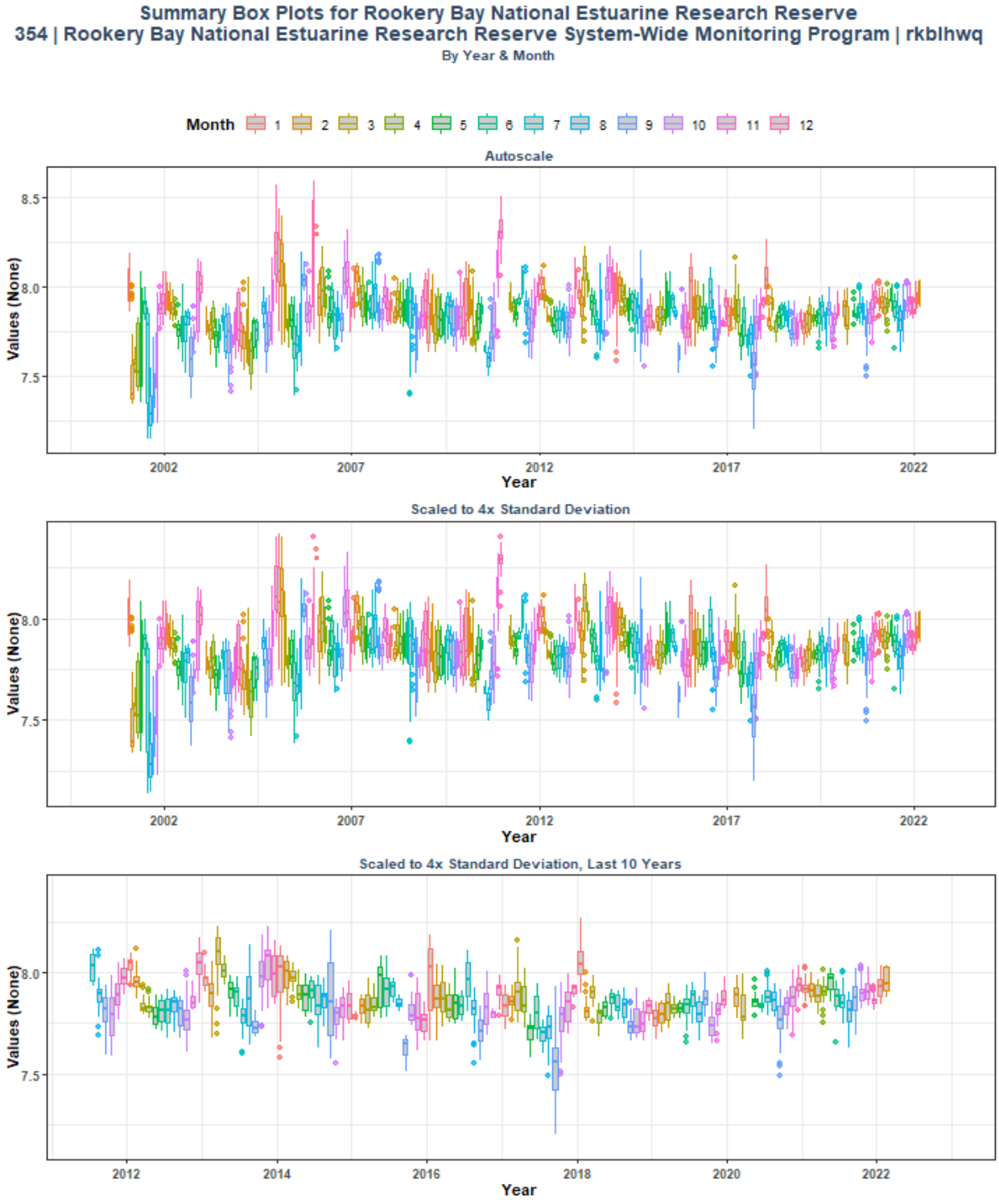

Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfuwq
By Year & Month
Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (None)
Year
Scaled to 4x Standard Deviation
Values (None)
Year
Scaled to 4x Standard Deviation, Last 10 Years
Values (None)
Year


Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfuwq
By Month
Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (None)
8.5
8.0
7.5
7.0
3
6
9
12
Month
Scaled to 4x Standard Deviation
Values (None)
8.0
7.5
7.0
3
6
9
12
Month
Scaled to 4x Standard Deviation, Last 10 Years
Values (None)
8.0
7.5
7.0
3
6
9
12
Month

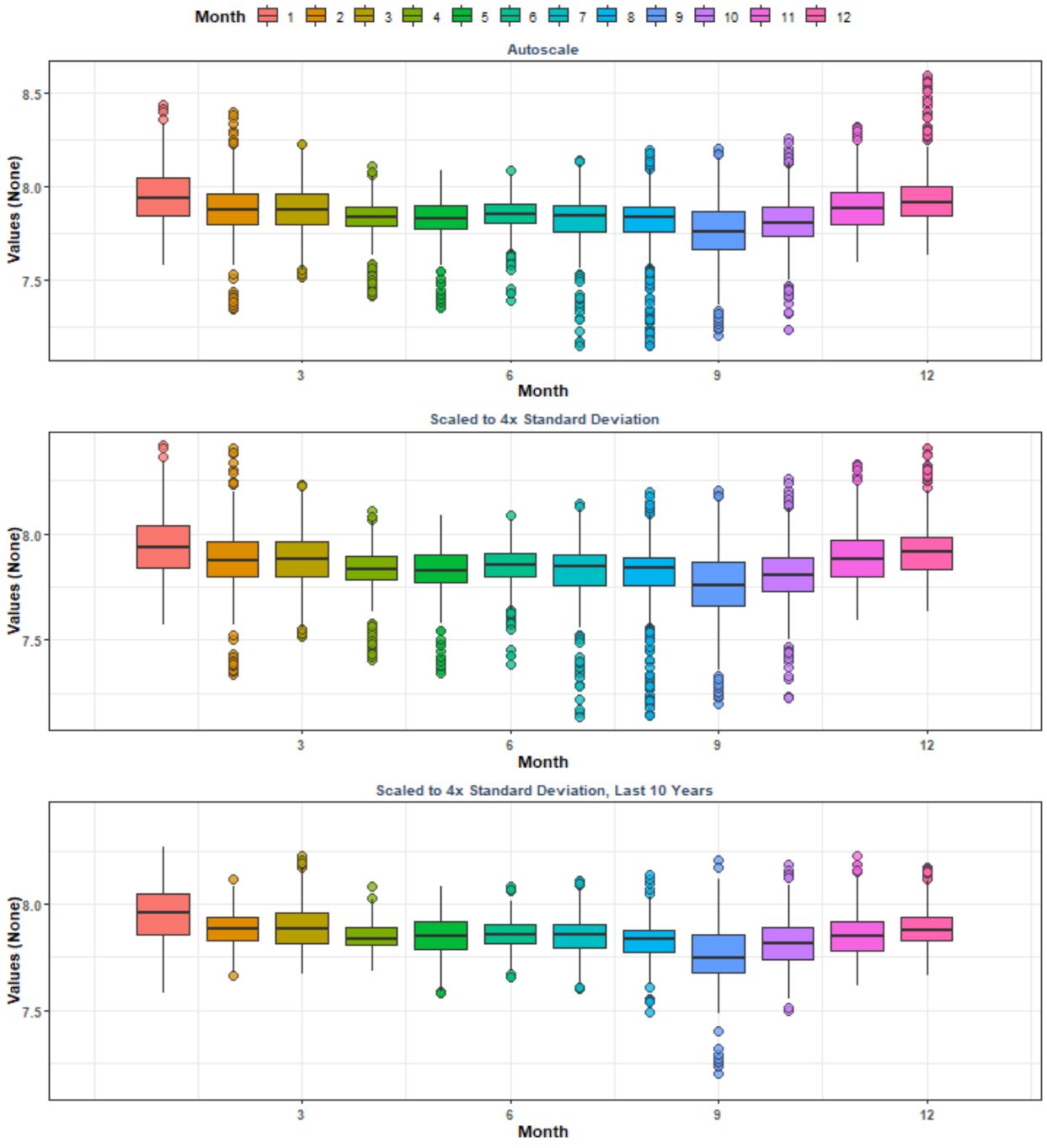
Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkblhwq

By Year



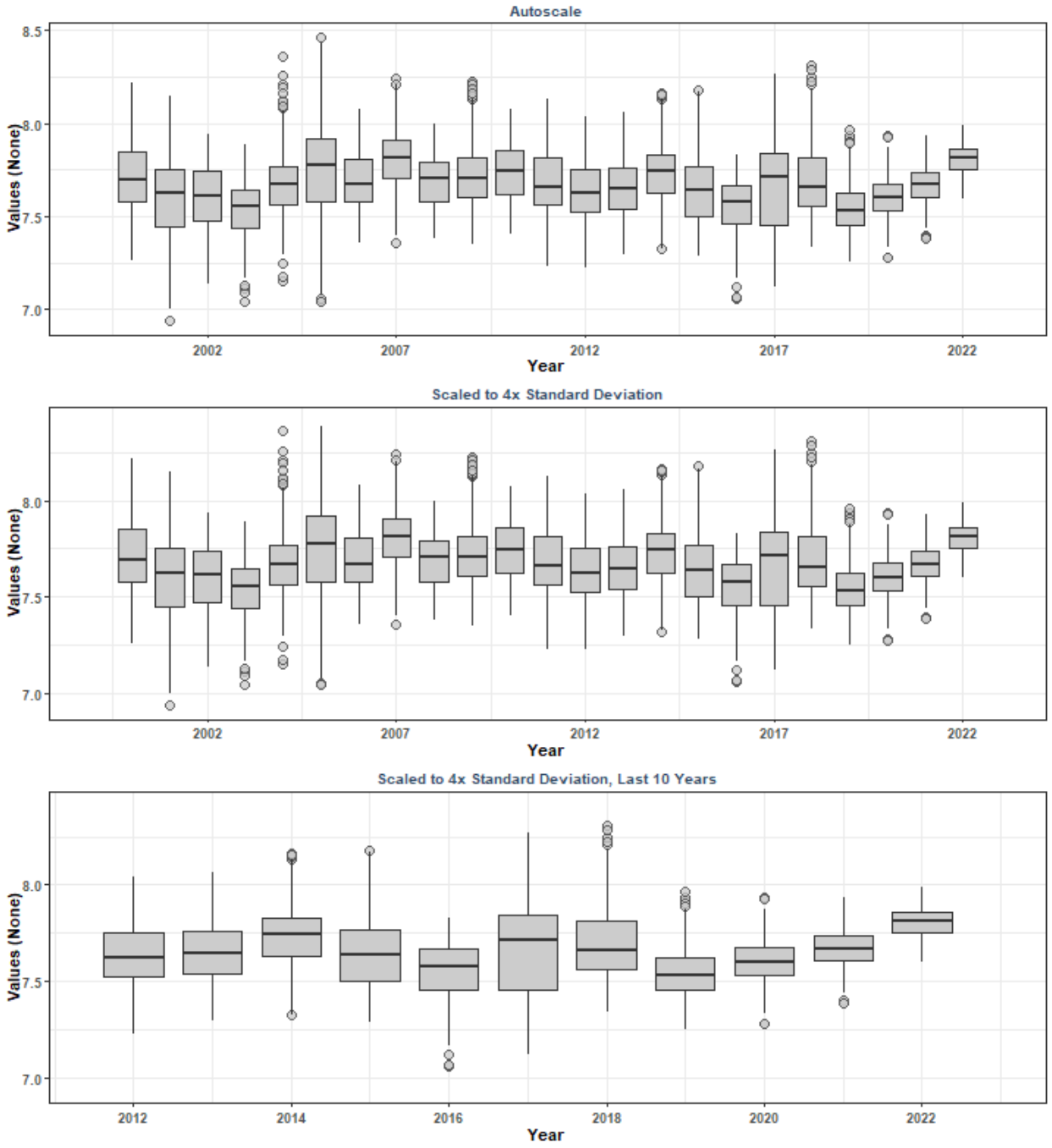

Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkblhwq
By Year & Month
Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (None)
8.5
8.0
7.5
2002
2007
2012
2017
2022
Year
Scaled to 4x Standard Deviation
Values (None)
8.0
7.5
2002
2007
2012
2017
2022
Year
Scaled to 4x Standard Deviation, Last 10 Years
Values (None)
8.0
7.5
2012
2014
2016
2018
2020
2022
Year

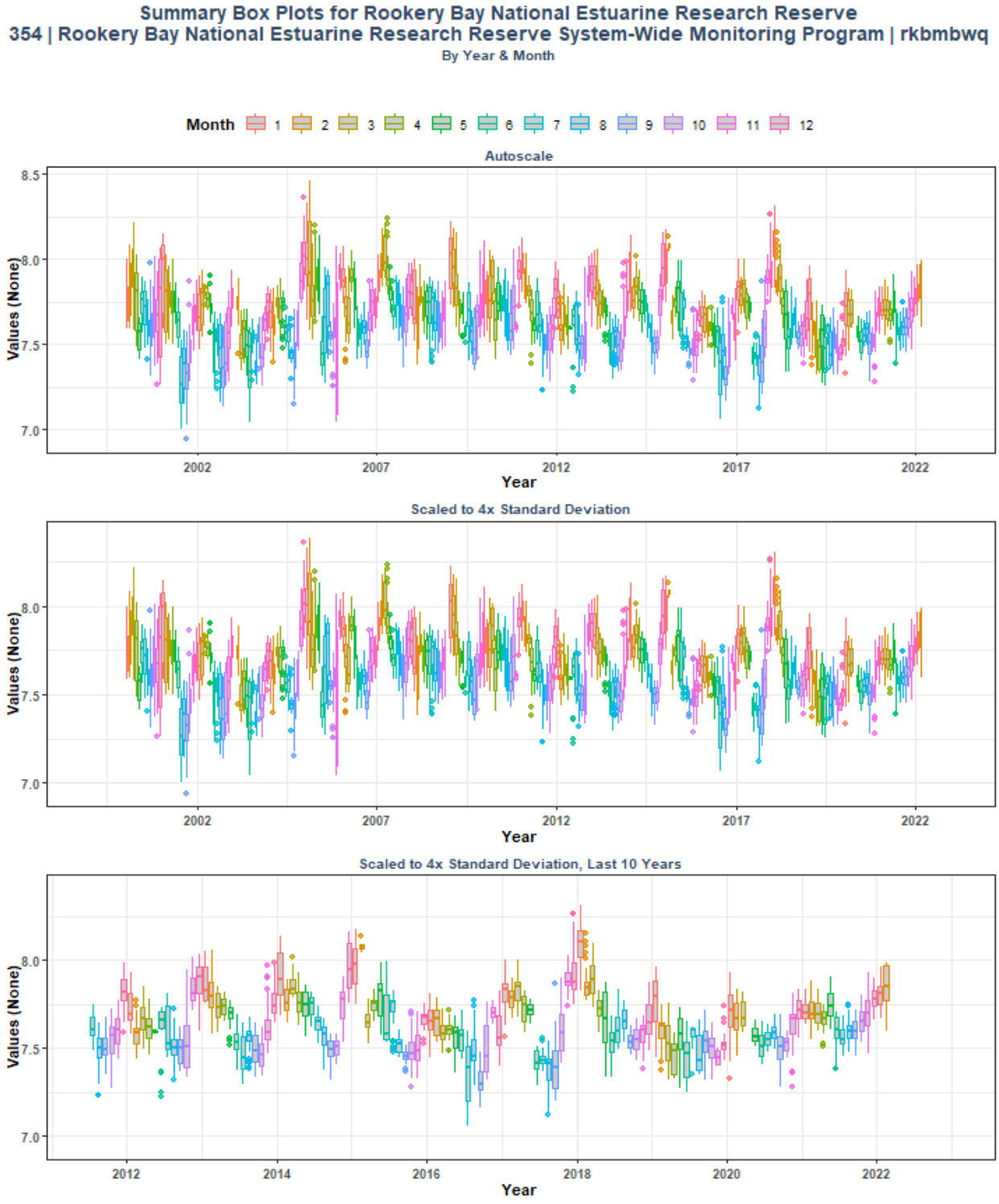
Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkblhwq
By Month



Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbmbwq

By Year




Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbmbwq
By Year & Month
Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (None)
Year
Scaled to 4x Standard Deviation
Values (None)
Year
Scaled to 4x Standard Deviation, Last 10 Years
Values (None)
Year

Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbmbwq
By Month