SEACAR Continuous Water Quality Analysis: SW Region for Turbidity

Last compiled on 19 May, 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.

```r
library(knitr)
library(data.table)
library(dplyr)
library(lubridate)
library(ggplot2)
library(ggpubr)
library(scales)
library(EnvStats)
library(tidyr)
options(scipen = 999)
```

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.

```r
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))
```

```
## `summarise()` has grouped output by 'ManagedAreaName', 'ProgramID', 'ProgramName', 'ProgramLocationI
## `.groups` argument.
```

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

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_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_Years <- as.data.table(Mon_Years[
   order(Mon_Years$MonitoringID), ])
Mon_Years$Enough_Time <- ifelse(Mon_Years$Y < 5, FALSE, TRUE)
data <- merge.data.frame(data, Mon_Years[,c("MonitoringID", "Enough_Time")],
                         by = "MonitoringID")
# data$Exclude_MonitoringID <- is.element(data$MonitoringID,
#                                         Mon_Years$MonitoringID[
#                                            Mon_Years$Enough_Time == FALSE])
data$Use_In_Analysis <- ifelse(data$Include == TRUE &
                                  data$Enough_Time == 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.

```r
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)
   }, warning = function(w) {
      print(w)
   }, error = function(e) {
      print(e)
   }, finally = {
      if (!exists("tau")) {
         tau <- NULL
      }
      if (!exists("p")) {
         p <- NULL
      }
      if (!exists("slope")) {
         slope <- NULL
      }
      if (!exists("intercept")) {
         intercept <- NULL
```

```
    }
    if (!exists("trend")) {
      trend <- NULL
    }
  })
  KT <-c(unique(data$MonitoringID),
         independent,
         stats.median,
         nrow(data),
         stats.minYear,
         stats.maxYear,
         tau,
         p,
         slope,
         intercept,
         trend)
  return(KT)
}
runStats <- function(data) {
  data$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[11])) {
    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$ManagedAreaName
c_names <- c("MonitoringID", "Independent", "Median", "N", "EarliestYear",
             "LatestYear", "tau", "p", "SennSlope", "SennIntercept", "Trend")
if(n==0){
   c_names <- c("AreaID", "ManagedAreaName", "ProgramID", "ProgramName",
                "ProgramLocationID", "ParameterName", "RelativeDepth",
                "Independent", "Median", "N", "EarliestYear", "LatestYear",
                "tau", "p", "SennSlope", "SennIntercept", "Trend")
   KT.Stats <- data.frame(matrix(ncol=17, nrow=0))
   colnames(KT.Stats) <- c_names
   fwrite(KT.Stats, paste0(out_dir,"/", param_name, "_", region,
                           "_KendallTau_Stats.txt"), sep = "|")
} else{
   for (i in 1:n) {
      values <- data[data$Use_In_Analysis == TRUE &
                        data$MonitoringID == Mon_IDs[i], ]
      if (nrow(values) > 0) {
         KT.Stats <- runStats(values)
      }
   }
   KT.Stats <- as.data.frame(KT.Stats)
   if(dim(KT.Stats)[2]==1){
      KT.Stats <- as.data.frame(t(KT.Stats))
   }

   c_names <- c("MonitoringID", "Independent", "Median", "N", "EarliestYear",
                "LatestYear", "tau", "p", "SennSlope", "SennIntercept", "Trend")
   colnames(KT.Stats) <- c_names
   rownames(KT.Stats) <- seq(1:nrow(KT.Stats))
   KT.Stats$Independent <- as.logical(KT.Stats$Independent)
   KT.Stats$Median <- as.numeric(KT.Stats$Median)
   KT.Stats$N <- as.integer(KT.Stats$N)
   KT.Stats$EarliestYear <- as.integer(KT.Stats$EarliestYear)
   KT.Stats$LatestYear <- as.integer(KT.Stats$LatestYear)
   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_Years[,-c("Y", "Enough_Time")],
                                KT.Stats, by = "MonitoringID")
   KT.Stats$MonitoringID <- NULL
   fwrite(KT.Stats, paste0(out_dir,"/", param_name, "_", region,
                            "_KendallTau_Stats.txt"), sep = "|")
   KT.Stats$MonitoringID <- Mon_IDs
}
```

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.

```
   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(outlier.size = 0.5) +
      labs(subtitle = "Autoscale", x = "Year",
           y = paste0("Values (", unit, ")")) +
      theme_bw() +
      theme(axis.text.x = element_text(face = "bold"),
            axis.text.y = element_text(face = "bold"))

   p2 <- ggplot(data = data[data$Include == TRUE, ],
                aes(x = Year, y = ResultValue, group = Year)) +
      geom_boxplot(outlier.size = 0.5) +
      labs(subtitle = "Scaled to 4x Standard Deviation", x = "Year",
           y = paste0("Values (", unit, ")")) +
      ylim(0, y_scale) +
      theme_bw() + theme(axis.text.x = element_text(face = "bold"),
                         axis.text.y = element_text(face = "bold"))

   p3 <- ggplot(data = data[data$Include == TRUE, ],
                aes(x = as.integer(Year), y = ResultValue, group = Year)) +
      geom_boxplot(outlier.size = 0.5) +
      labs(subtitle = "Scaled to 4x Standard Deviation, Last 10 Years",
           x = "Year", y = paste0("Values (", unit, ")")) +
      ylim(0, y_scale) +
      scale_x_continuous(limits = c(max(data$Year) - 10.5, max(data$Year)+0.5),
                         breaks = seq(max(data$Year) - 10, max(data$Year), 2)) +
      theme_bw() +
      theme(axis.text.x = element_text(face = "bold"),
            axis.text.y = element_text(face = "bold"))

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

   p0 <- ggplot() + labs(title = "Summary Box Plots for Entire Data",
                         subtitle = "By Year") + theme_bw() +
      theme(plot.title = element_text(face="bold", hjust=0.5),
            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.

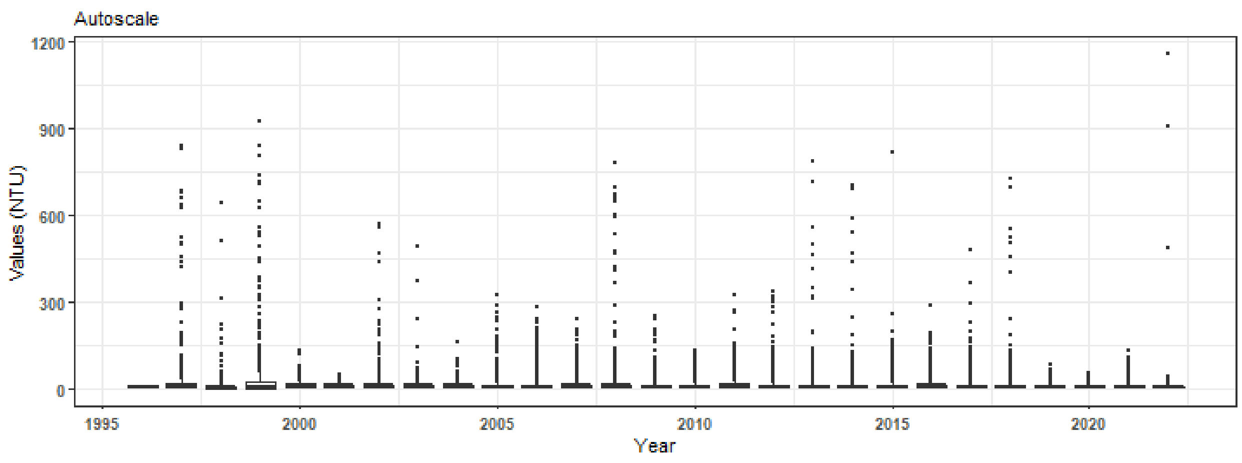
```
p1 <- ggplot(data = data[data$Include == TRUE, ],
             aes(x = YearMonthDec, y = ResultValue,
                 group = YearMonth, color = as.factor(Month))) +
  geom_boxplot(outlier.size = 0.5) +
  labs(subtitle = "Autoscale", x = "Year",
       y = paste0("Values (", unit, ")"), color="Month") +
  theme_bw() +
  theme(legend.position = "top", legend.box = "horizontal",
        axis.text.x = element_text(face = "bold"),
        axis.text.y = element_text(face = "bold")) +
  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(outlier.size = 0.5) +
  labs(subtitle = "Scaled to 5x Standard Deviation",
       x = "Year", y = paste0("Values (", unit, ")")) +
  ylim(0, y_scale) +
  theme_bw() +
  theme(legend.position = "none", axis.text.x = element_text(face = "bold"),
        axis.text.y = element_text(face = "bold"))

p3 <- ggplot(data = data[data$Include == TRUE, ],
             aes(x = YearMonthDec, y = ResultValue,
                 group = YearMonth, color = as.factor(Month))) +
  geom_boxplot(outlier.size = 0.5) +
  labs(subtitle = "Scaled to 5x Standard Deviation, Last 10 Years",
       x = "Year", y = paste0("Values (", unit, ")")) +
  ylim(0, y_scale) +
  scale_x_continuous(limits = c(max(data$Year) - 10.5, max(data$Year)+0.5),
                     breaks = seq(max(data$Year) - 10, max(data$Year), 2)) +
  theme_bw() +
  theme(legend.position = "none", axis.text.x = element_text(face = "bold"),
        axis.text.y = element_text(face = "bold"))
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") + theme_bw() +
  theme(plot.title = element_text(face="bold", hjust=0.5),
        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))
```

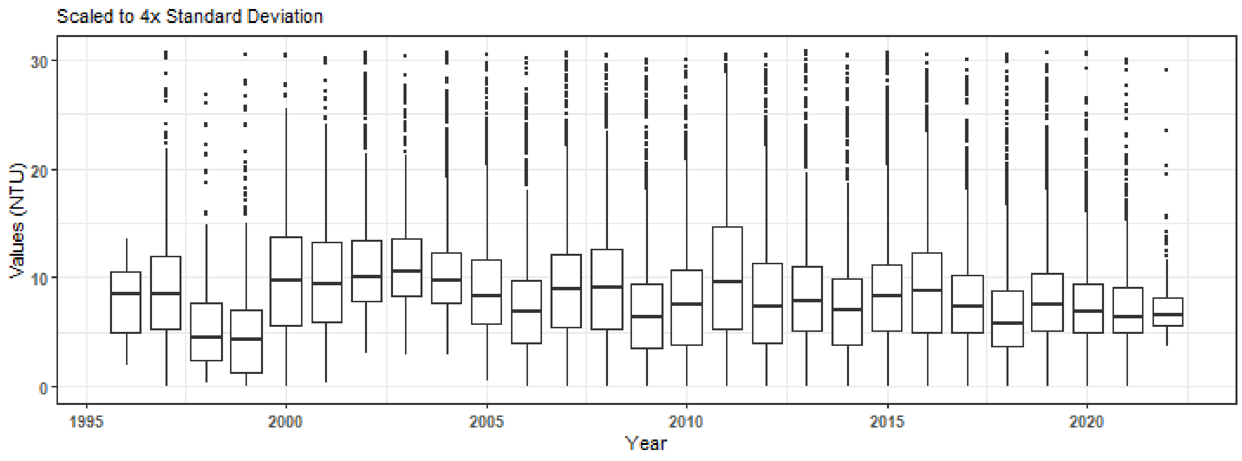
The following box plots are grouped by month with fill color being related to the month. This is designed to view potential seasonal trends.

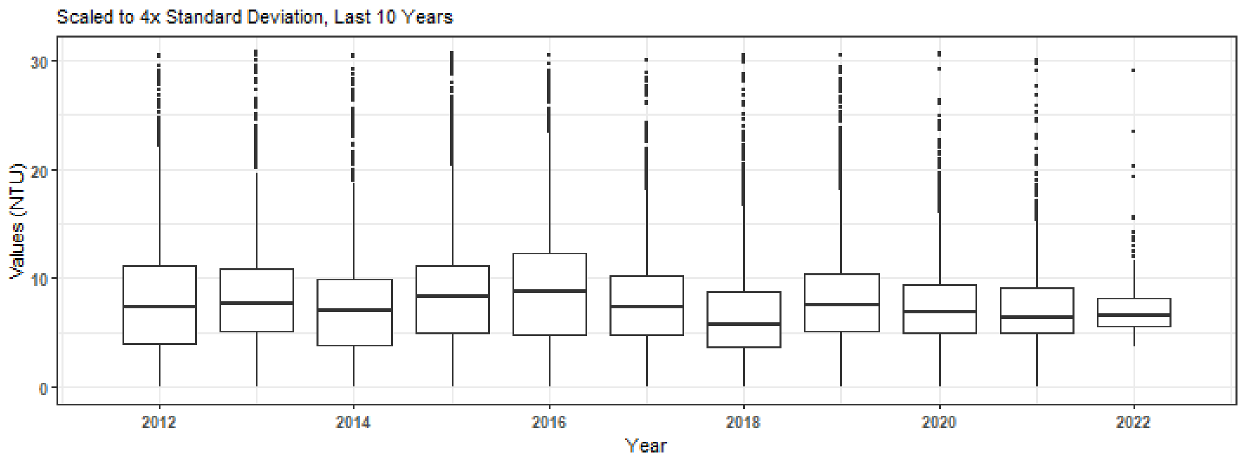
```
  p1 <- ggplot(data = data[data$Include == TRUE, ],
               aes(x = Month, y = ResultValue,
                   group = Month, fill = as.factor(Month))) +
    geom_boxplot(outlier.size = 0.5) +
    labs(subtitle = "Autoscale", x = "Month",
         y = paste0("Values (", unit, ")"), fill="Month") +
    scale_x_continuous(limits = c(0, 13), breaks = seq(3, 12, 3)) +
    theme_bw() +
    theme(legend.position = "top", legend.box = "horizontal",
          axis.text.x = element_text(face = "bold"),
          axis.text.y = element_text(face = "bold")) +
    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(outlier.size = 0.5) +
    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)) +
    theme_bw() +
    theme(legend.position = "none", axis.text.x = element_text(face = "bold"),
          axis.text.y = element_text(face = "bold"))

  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(outlier.size = 0.5) +
    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)) +
    theme_bw() +
    theme(legend.position = "none", axis.text.x = element_text(face = "bold"),
          axis.text.y = element_text(face = "bold"))
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") + theme_bw() +
   theme(plot.title = element_text(face="bold", hjust=0.5),
         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

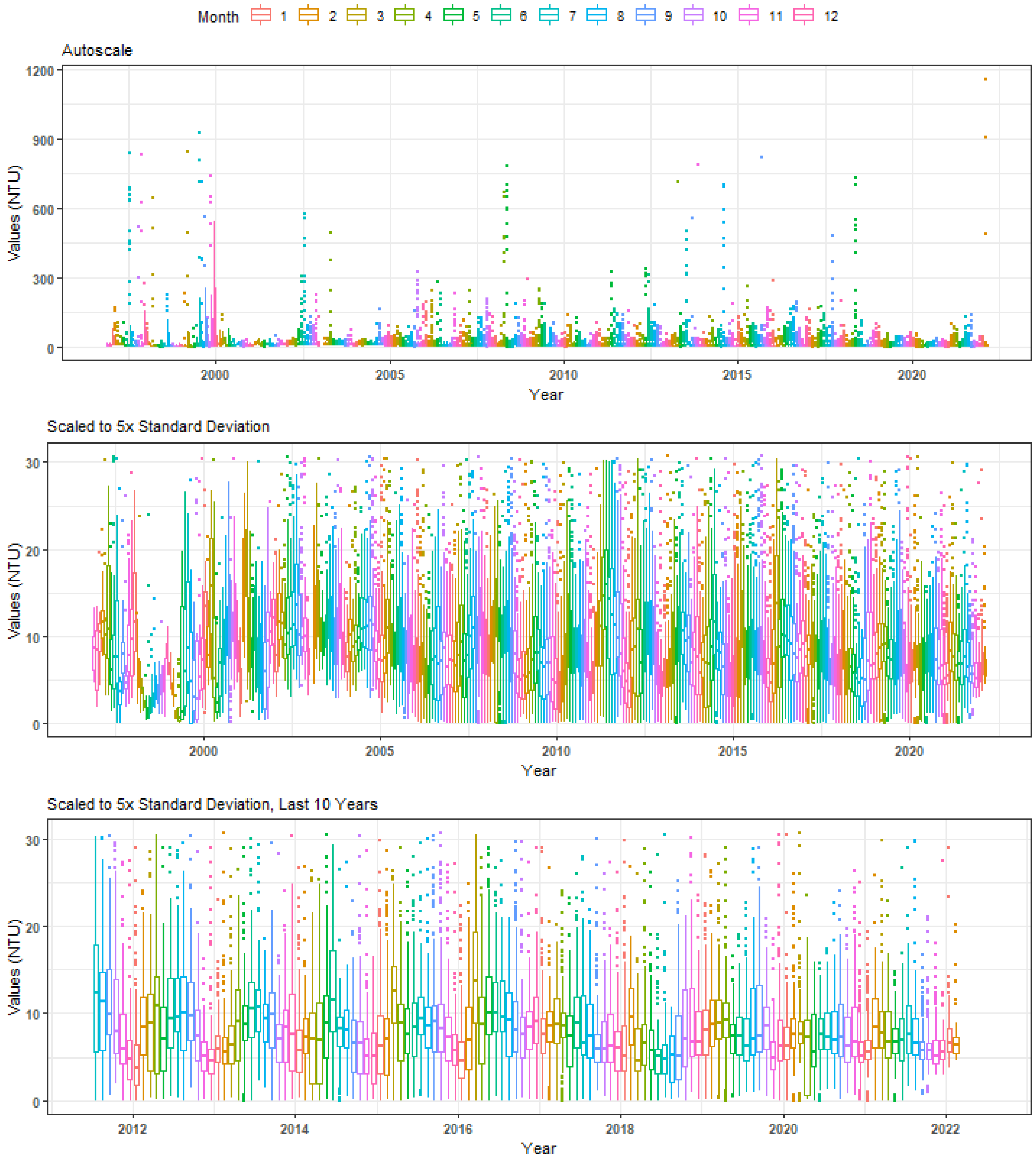


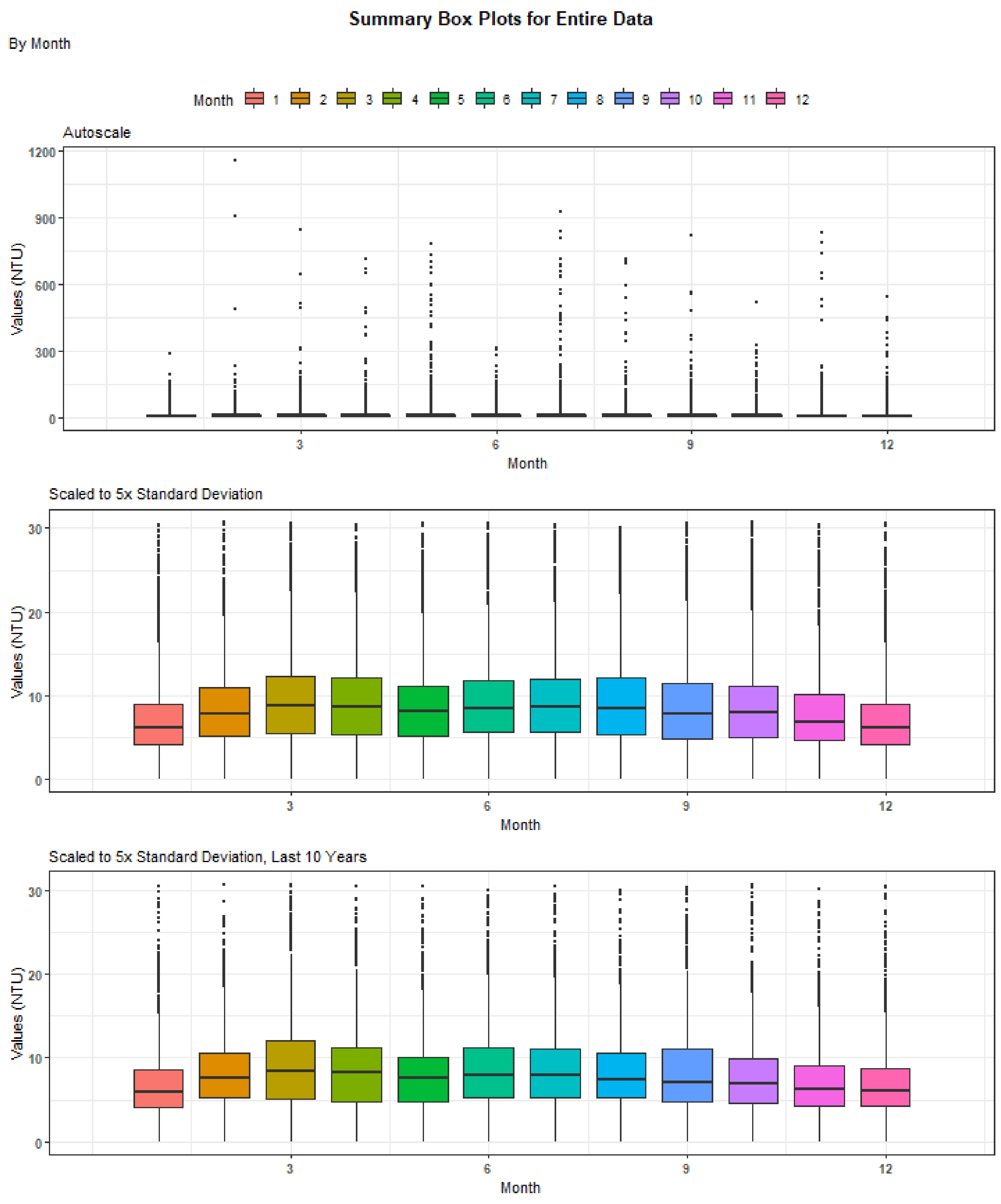




Summary Box Plots for Entire Data

By Year & Month



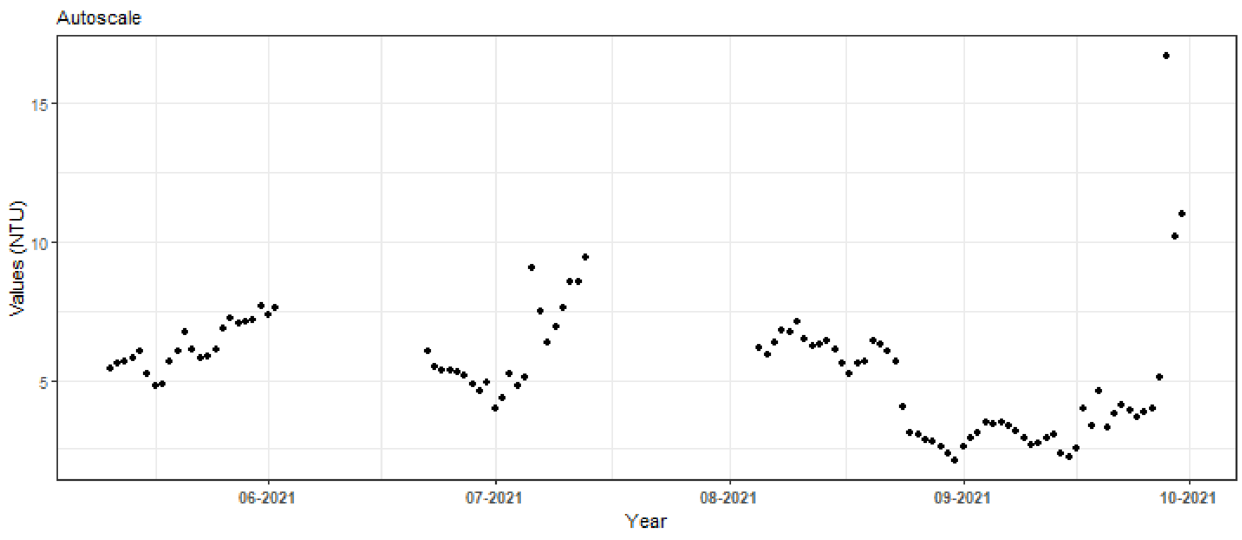


Appendix II: Excluded Monitoring Locations

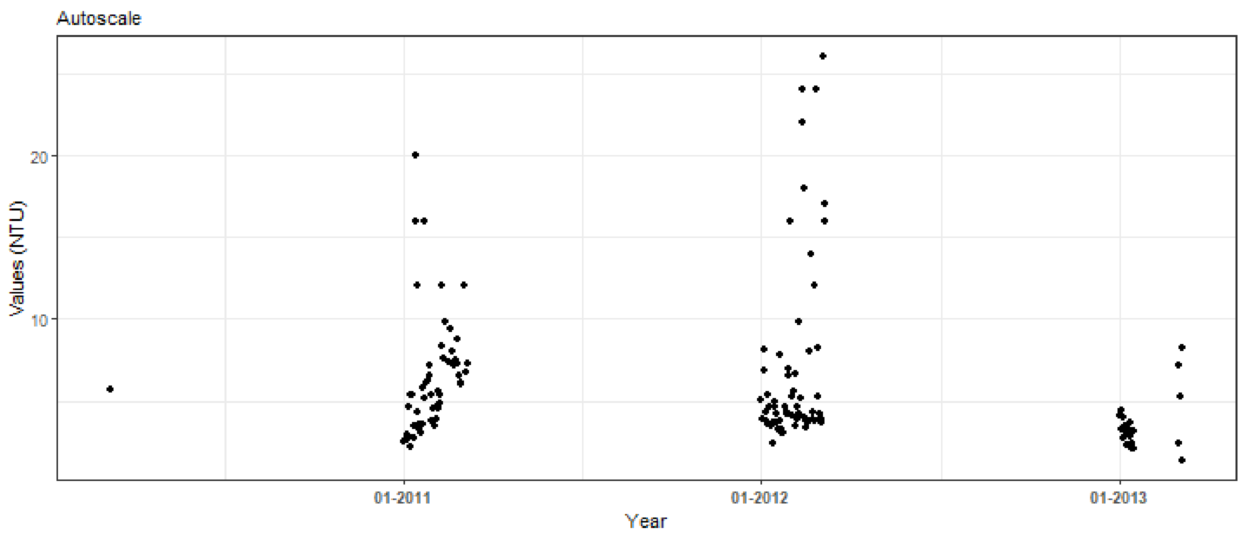
Scatter plots of data values are created for monitoring locationss that have fewer than 5 separate years of data entries.

```r
Mon_Exclude <- Mon_Years[Mon_Years$Enough_Time==FALSE,]
Mon_Exclude <- Mon_Exclude[order(Mon_Exclude$MonitoringID),]
z=length(Mon_Exclude$MonitoringID)

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$Include == TRUE, ],
                 aes(x = SampleDate, y = ResultValue)) +
         geom_point() +
         labs(title=
                 paste0("Scatter Plot of Excluded Monitoring Location ",
                        MA_name, "\n", Mon_name, "\n(", Mon_Exclude$Y[i],
                        " Unique Years)"),
              subtitle="Autoscale", x = "Year",
              y = paste0("Values (", unit, ")")) +
         theme_bw() +
         theme(plot.title = element_text(face="bold", hjust=0.5),
               axis.text.x = element_text(face = "bold")) +
         scale_x_date(labels = date_format("%m-%Y"))
      print(p1)
   }
}
```

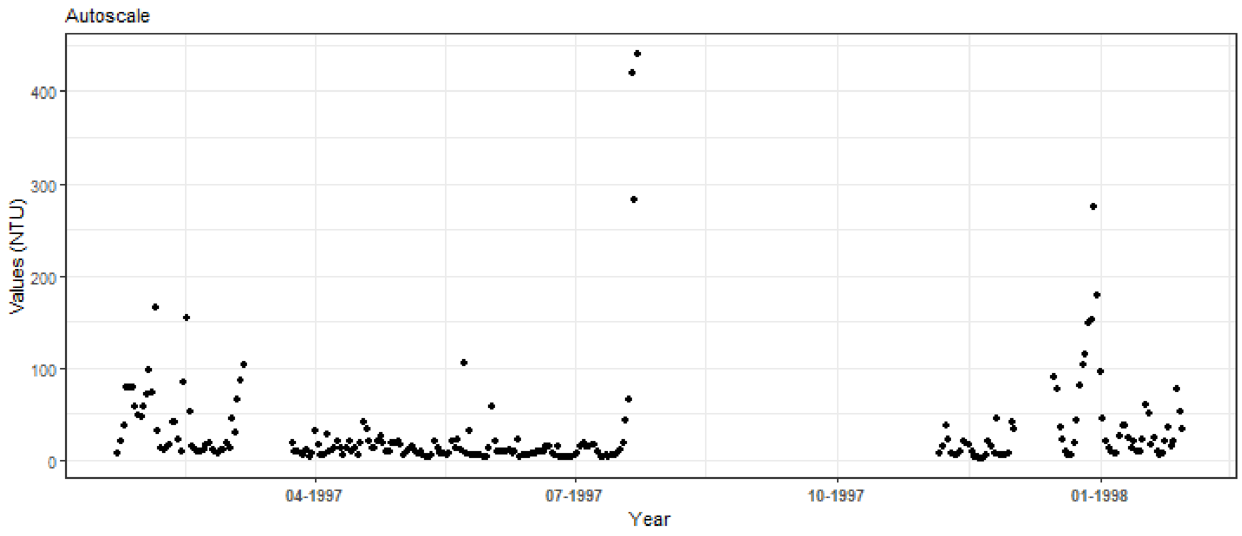
Scatter Plot of Excluded Monitoring Location Estero Bay Aquatic Preserve
474 | Estero Bay Aquatic Preserve Continuous Water Quality Monitoring | EB04
(1 Unique Years)



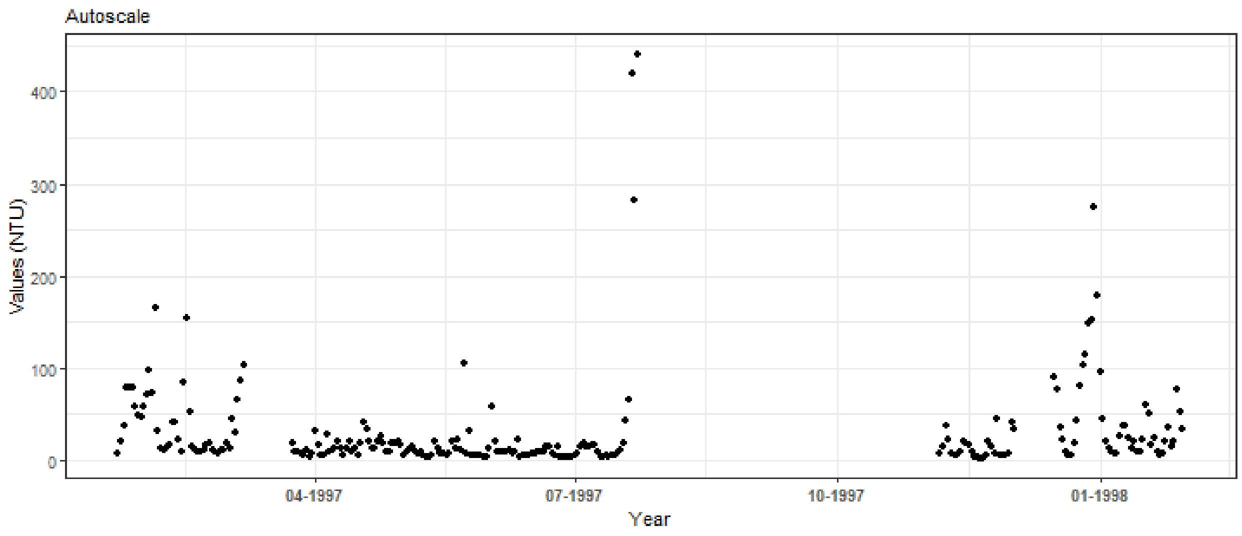
Scatter Plot of Excluded Monitoring Location Pine Island Sound Aquatic Preserve
7 | National Water Information System | 02293249
(4 Unique Years)

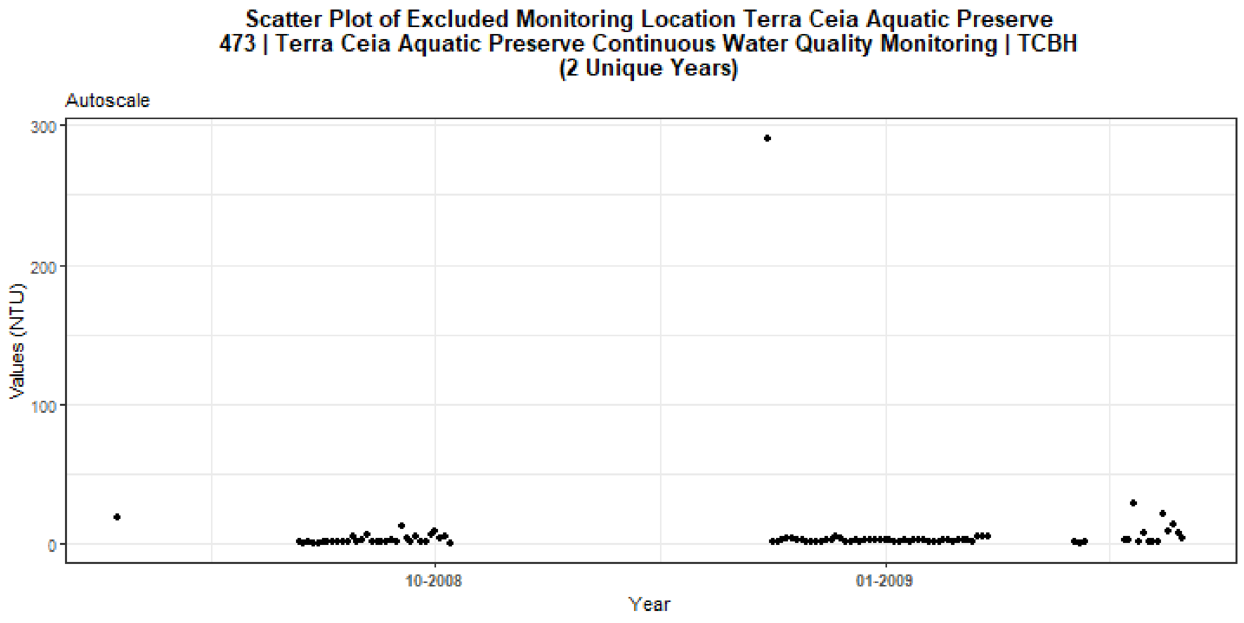


Scatter Plot of Excluded Monitoring Location Rookery Bay Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbbmwq
(2 Unique Years)



Scatter Plot of Excluded Monitoring Location Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbbmwq
(2 Unique Years)





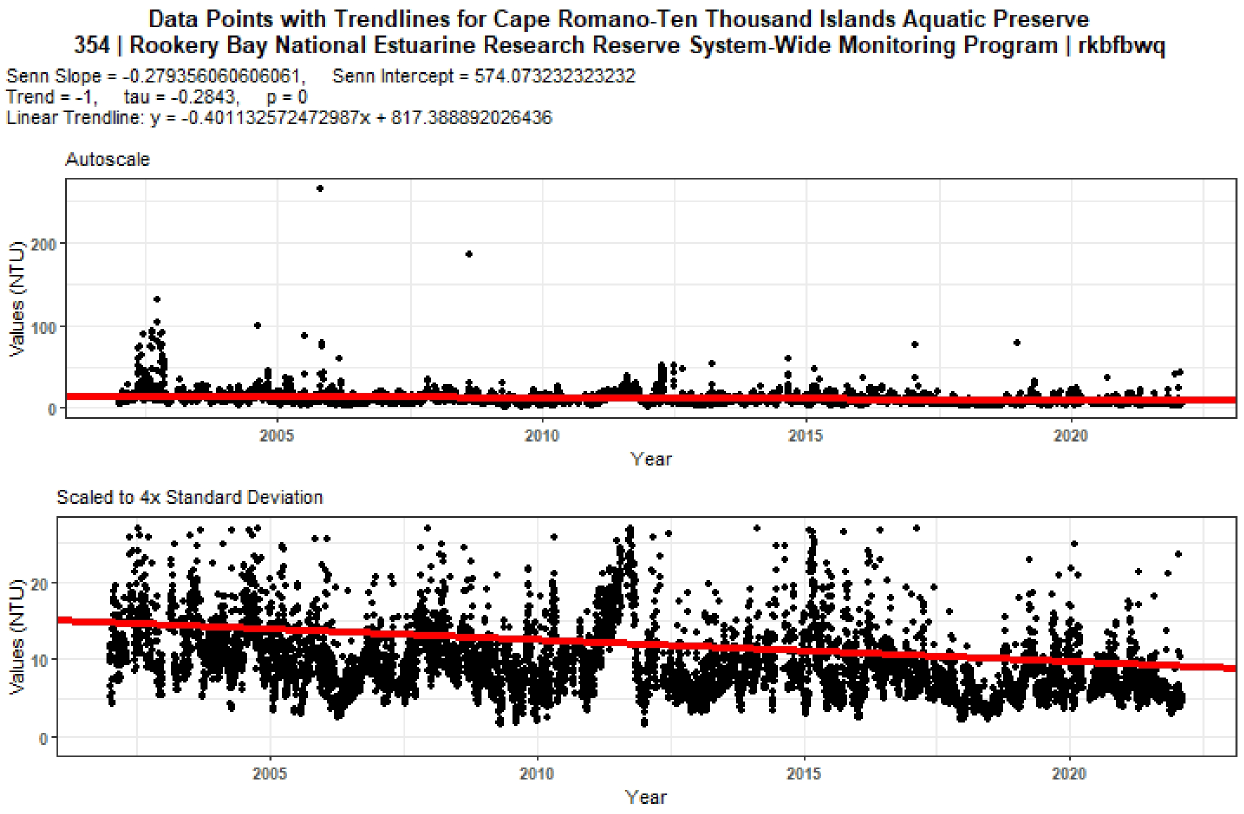
Appendix III: Monitoring Location Trendlines

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

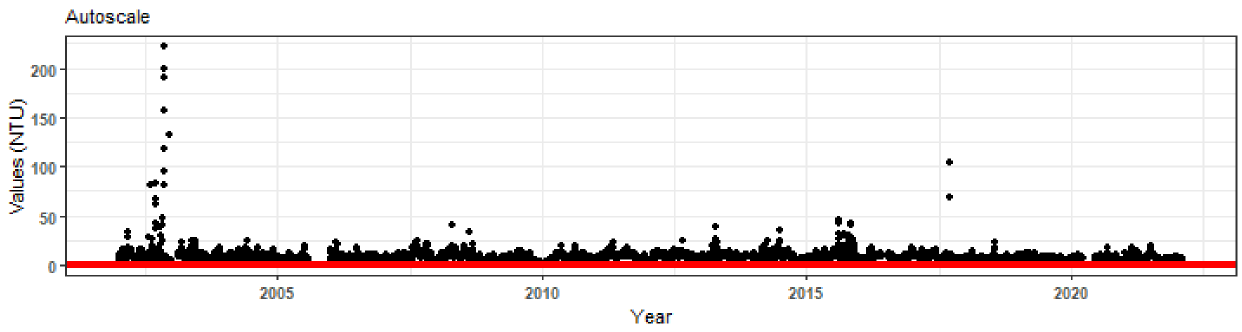
```
if(n==0){
   print("There are no monitoring locations that qualify.")
} else {
   for (i in 1:n) {
      plot_data <- data[data$Use_In_Analysis == TRUE &
                              data$MonitoringID == Mon_IDs[i],]
      year_lower <- min(plot_data$Year)
      year_upper <- max(plot_data$Year)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

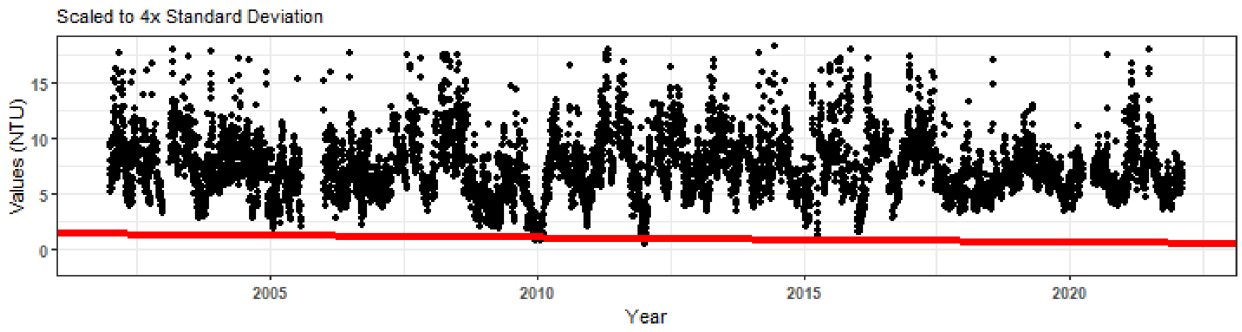
```
    sd_RV <- sd(plot_data$ResultValue[plot_data$ResultValue <
                                quantile(plot_data$ResultValue, 0.98)])
    x_scale <- ifelse(year_upper - year_lower > 30, 10, 5)
    y_scale <- mn_RV + 4 * sd_RV

    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]]
    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(size = 1.5) +
       geom_abline(aes(slope=s_slope, intercept=s_int),
                   color="red", size=1.5) +
       labs(subtitle = "Autoscale",
            x = "Year", y = paste0("Values (", unit, ")")) +
       theme_bw() +
       theme(axis.text.x = element_text(face = "bold"),
             axis.text.y = element_text(face="bold"))

    p2 <- ggplot(data = plot_data,
                 aes(x = DecDate, y = ResultValue)) +
       geom_point(size = 1.5) +
       geom_abline(aes(slope=s_slope, intercept=s_int),
                   color="red", size=1.5) +
       ylim(min_RV-0.1*y_scale, y_scale) +
       labs(subtitle = "Scaled to 4x Standard Deviation",
            x = "Year", y = paste0("Values (", unit, ")")) +
       theme_bw() +
       theme(axis.text.x = element_text(face = "bold"),
             axis.text.y = element_text(face="bold"))
    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)) +
          theme_bw() + theme(plot.title = element_text(face="bold", hjust=0.5),
                             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)))
    }
}
```



Data Points with Trendlines for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfuwq

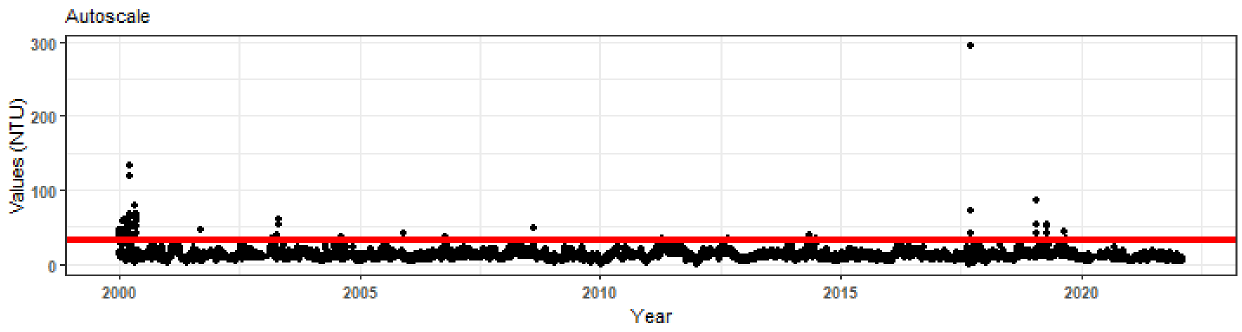
Senn Slope = -0.0401785714285714,   Senn Intercept = 81.8357279693486
Trend = -1,   tau = -0.0623,   p = 0
Linear Trendline: y = -0.108047779973858x + 225.314192635104

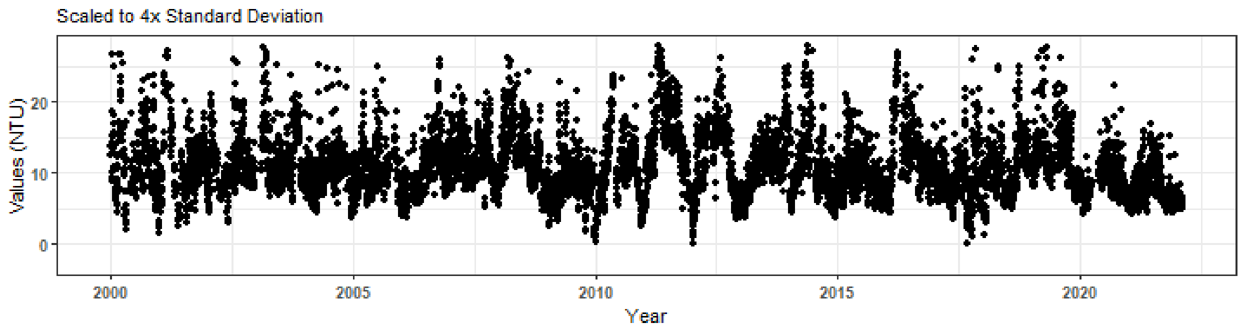




Data Points with Trendlines for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbmbwq

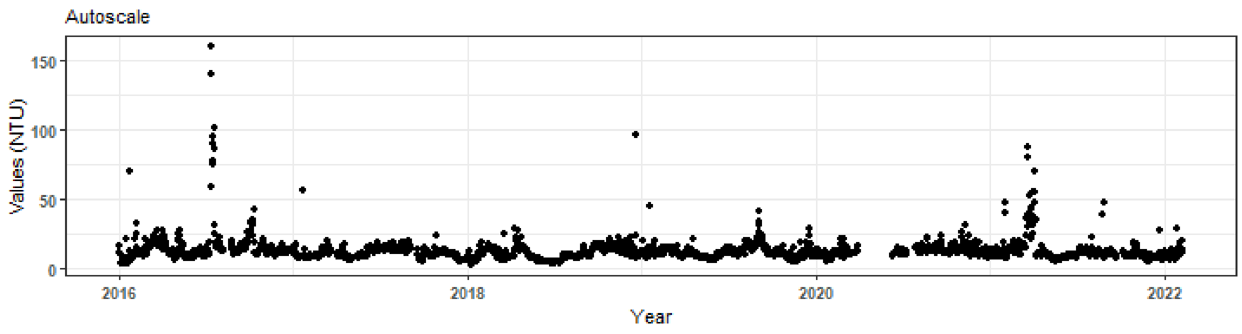
Senn Slope = -0.0920138888888888,   Senn Intercept = 219.111849937343
Trend = -1,   tau = -0.0966,   p = 0
Linear Trendline: y = -0.140821266927841x + 294.761797914514

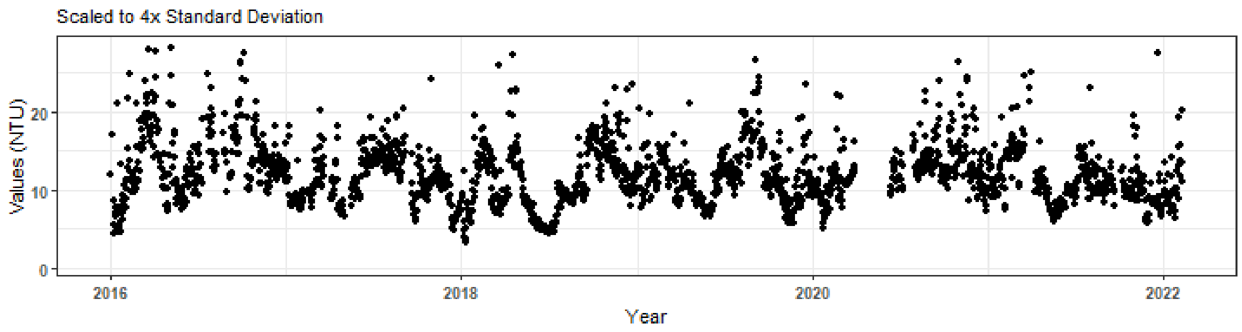




Data Points with Trendlines for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbpbwq

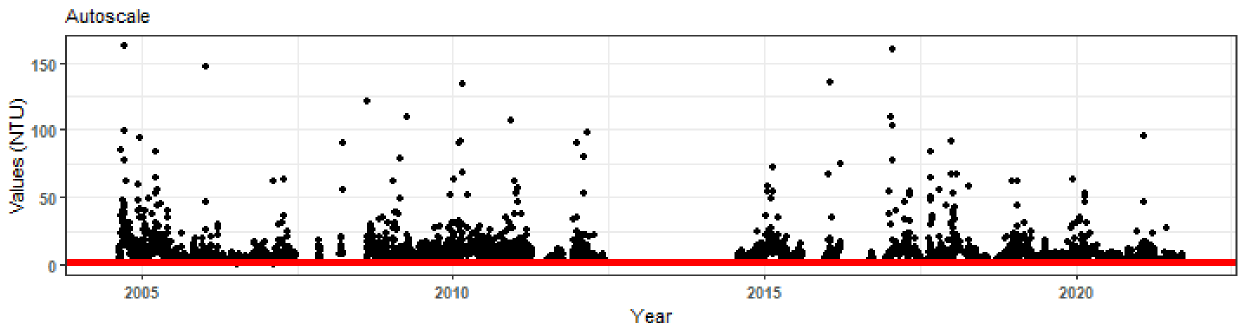
Senn Slope = -0.241522606382979,   Senn Intercept = 747.842859100878
Trend = -1,   tau = -0.0837,   p = 0
Linear Trendline: y = -0.380309781089862x + 780.858686876527

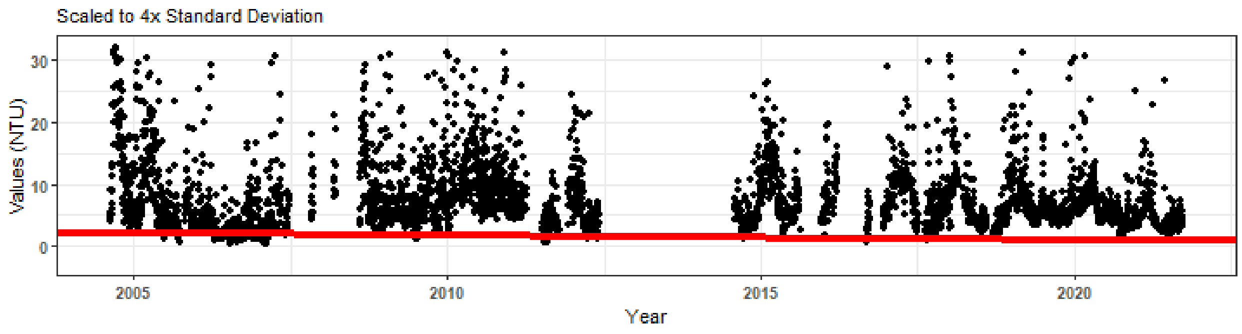




Data Points with Trendlines for Estero Bay Aquatic Preserve
474 | Estero Bay Aquatic Preserve Continuous Water Quality Monitoring | EB02

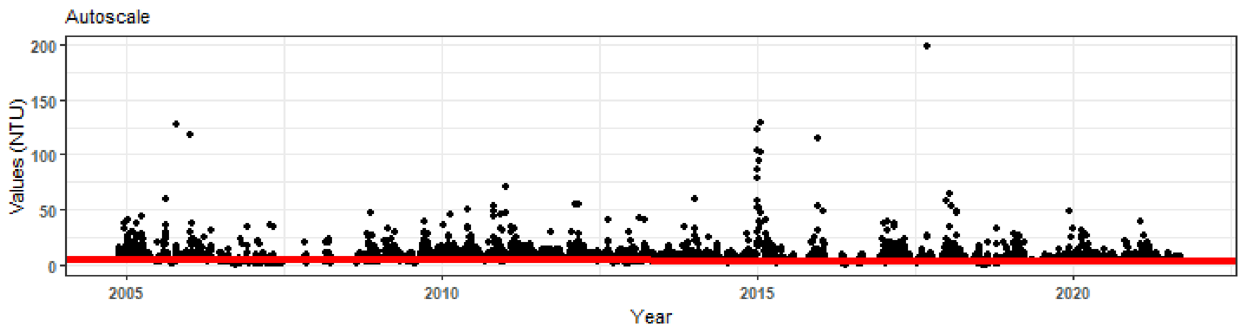
Senn Slope = -0.0763888888888889,   Senn Intercept = 155.361644345238
Trend = -1,   tau = -0.0712,   p = 0
Linear Trendline: y = -0.227085864968084x + 466.364035635387

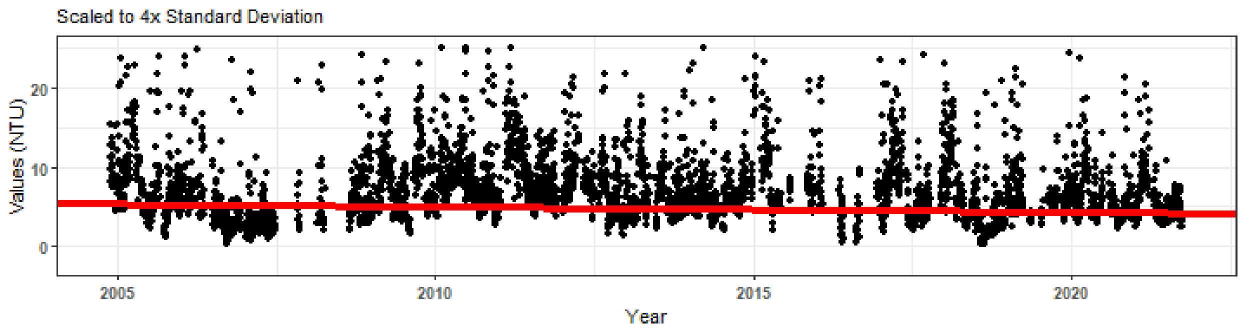




Data Points with Trendlines for Estero Bay Aquatic Preserve
474 | Estero Bay Aquatic Preserve Continuous Water Quality Monitoring | EB03

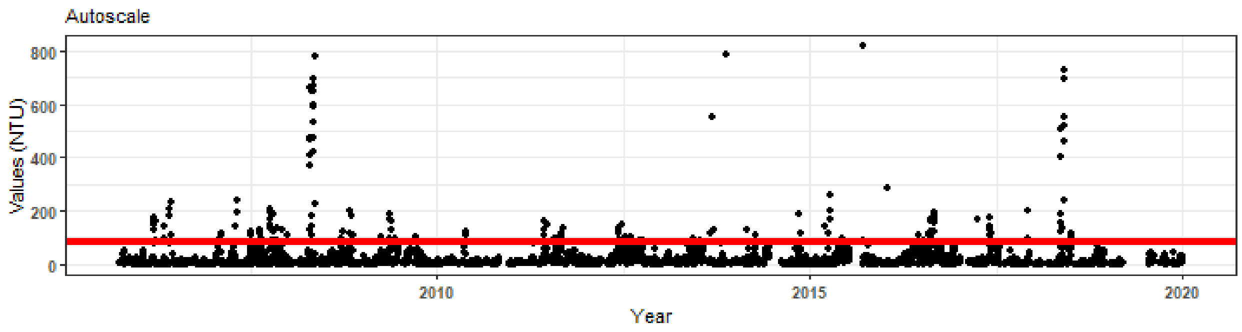
Senn Slope = -0.0657894736842105,   Senn Intercept = 137.191322055138
Trend = -1,   tau = -0.0652,   p = 0
Linear Trendline: y = -0.0885633186888404x + 186.500905886066

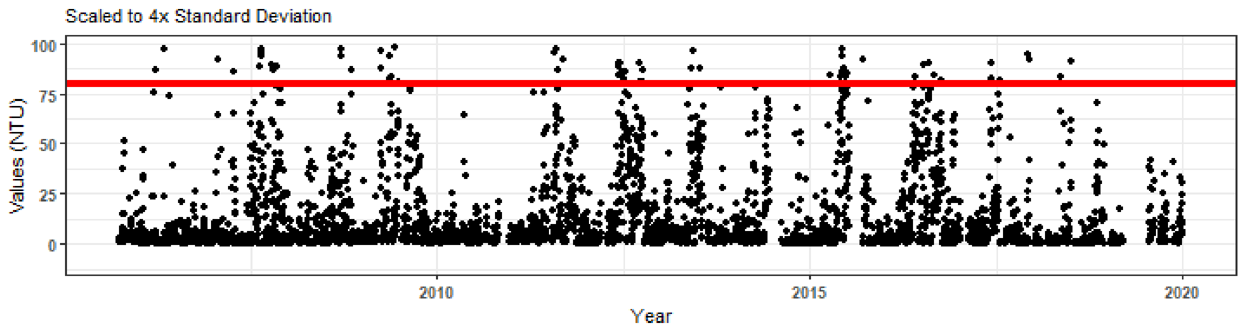




Data Points with Trendlines for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP1A

Senn Slope = -0.000582072965793896,   Senn Intercept = 81.3654967225446
Trend = 0,   tau = 0.0013,   p = 0.9178
Linear Trendline: y = -0.0529946307762367x + 124.905020413674

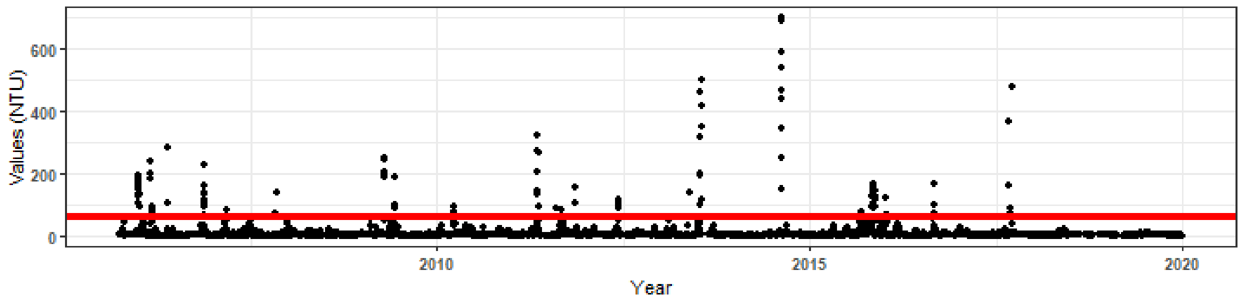




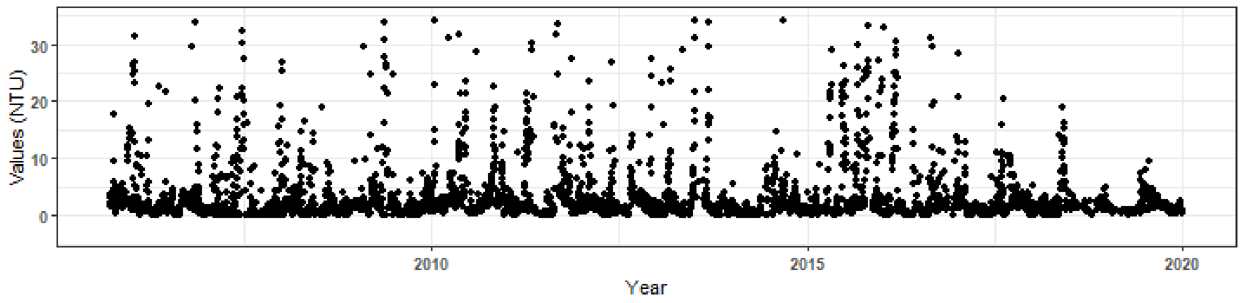
Data Points with Trendlines for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP2B

Senn Slope = -0.00686274509803922, Senn Intercept = 72.2443246580548
Trend = 0, tau = -0.0154, p = 0.0749
Linear Trendline: y = -0.223113196705047x + 456.594927733922

Autoscale



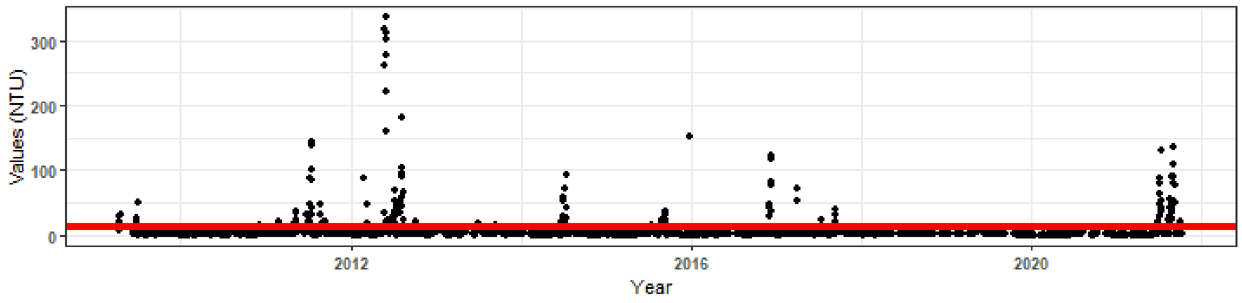
Scaled to 4x Standard Deviation



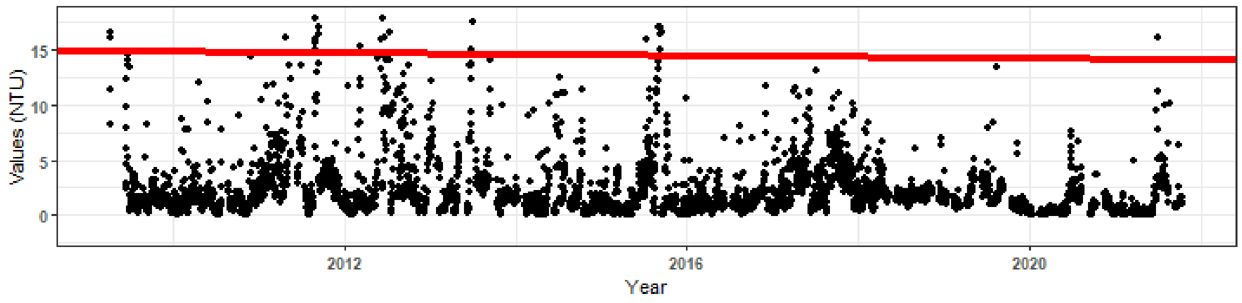
Data Points with Trendlines for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP3C

Senn Slope = -0.0590277777777778, Senn Intercept = 133.51810515873
Trend = -1, tau = -0.1083, p = 0
Linear Trendline: y = -0.191927795938666x + 391.212153901876

Autoscale

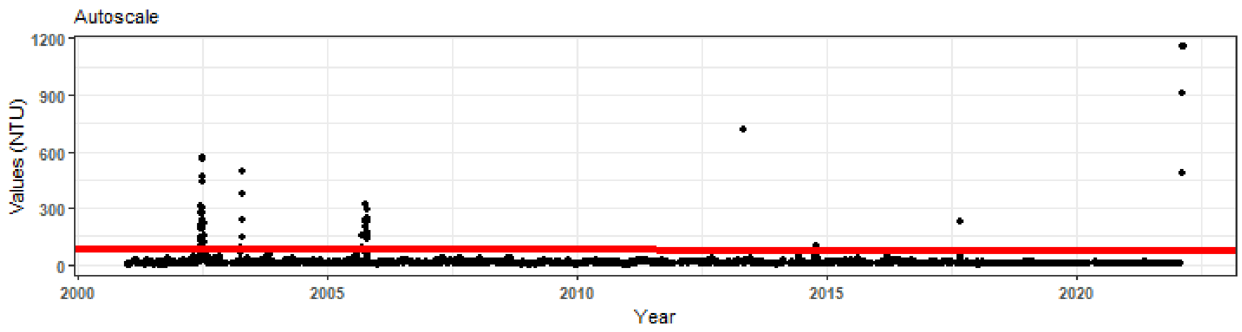


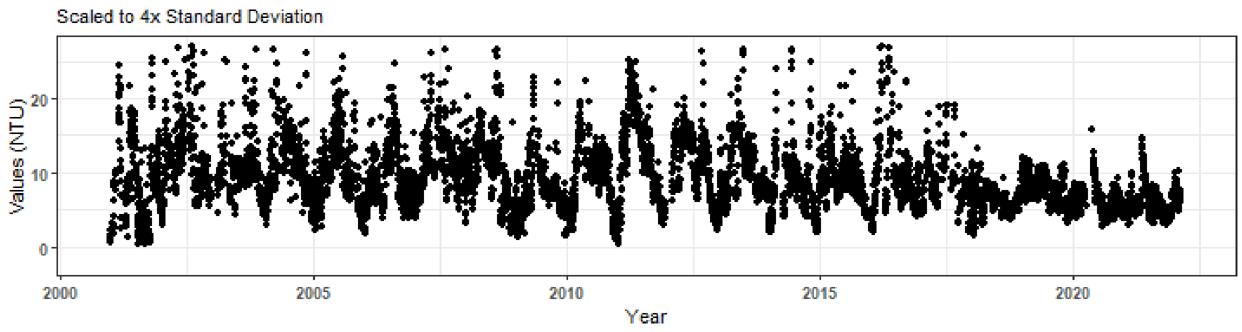
Scaled to 4x Standard Deviation



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

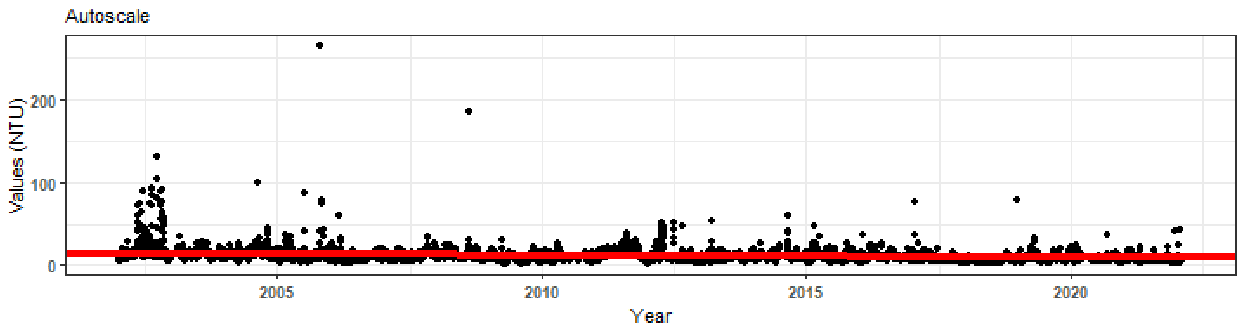
Senn Slope = -0.200231481481482, Senn Intercept = 483.441671364366
Trend = -1, tau = -0.2197, p = 0
Linear Trendline: y = -0.296629208558015x + 608.518399360601

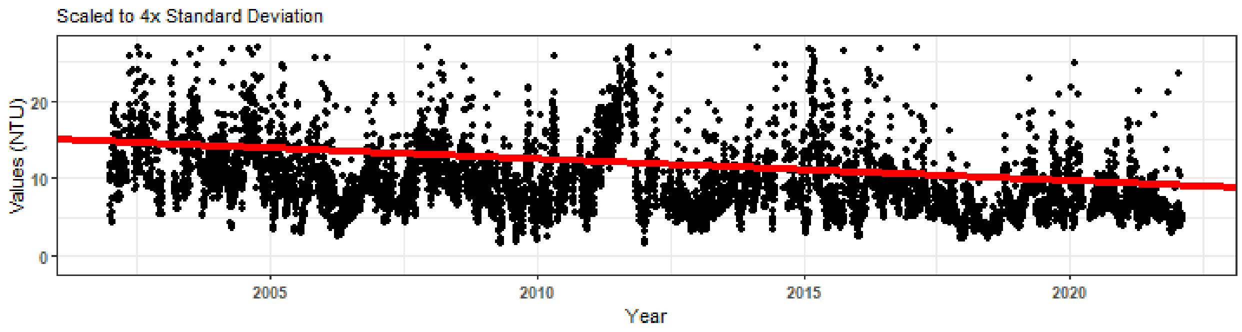




Data Points with Trendlines for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfbwq

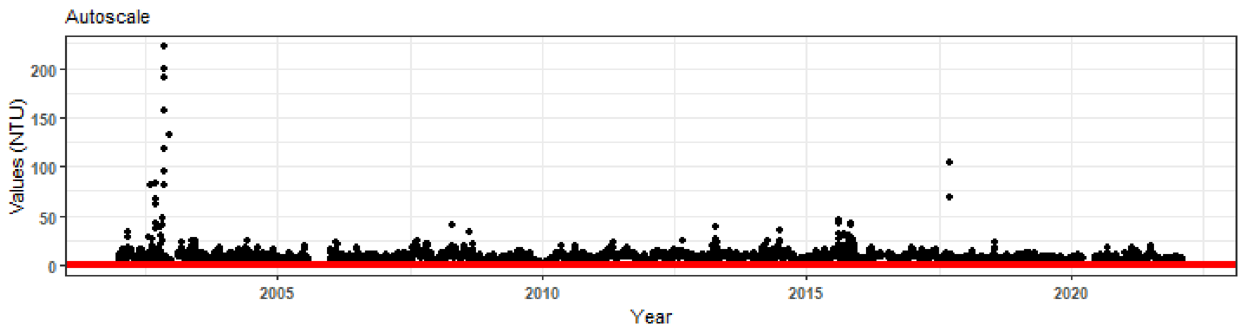
Senn Slope = -0.279356060606061, Senn Intercept = 574.073232323232
Trend = -1, tau = -0.2843, p = 0
Linear Trendline: y = -0.401132572472987x + 817.388892026436

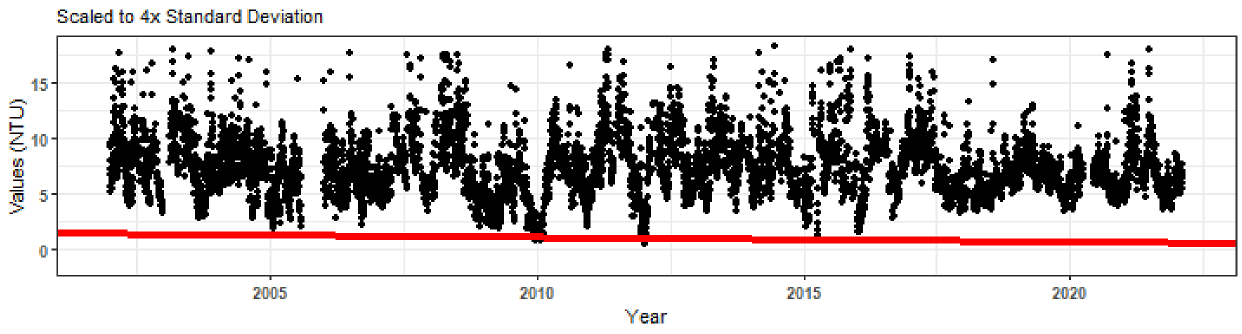




Data Points with Trendlines for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfuwq

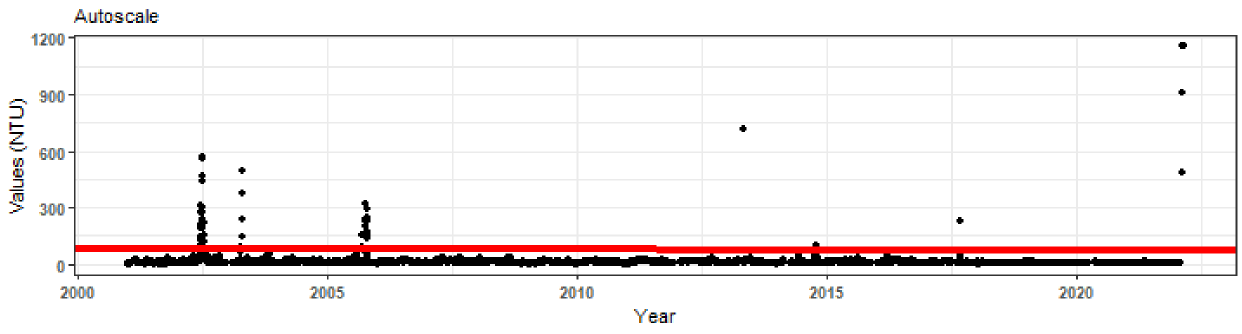
Senn Slope = -0.0401785714285714,   Senn Intercept = 81.8357279693486
Trend = -1,   tau = -0.0623,   p = 0
Linear Trendline: y = -0.108047779973858x + 225.314192635104

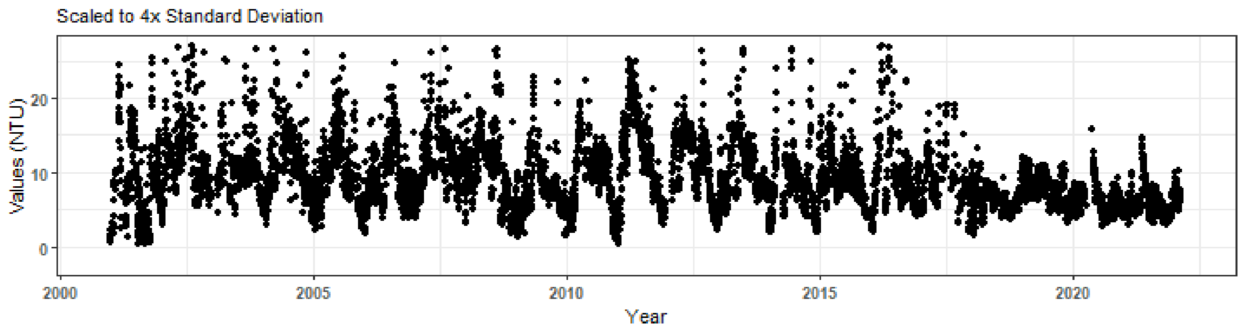




Data Points with Trendlines for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkblhwq

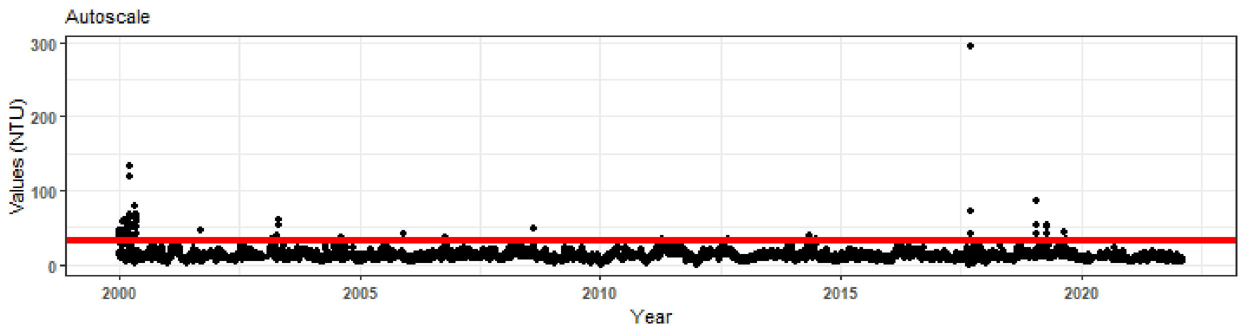
Senn Slope = -0.200231481481482,   Senn Intercept = 483.441671364366
Trend = -1,   tau = -0.2197,   p = 0
Linear Trendline: y = -0.29662920855801 5x + 608.518399360601

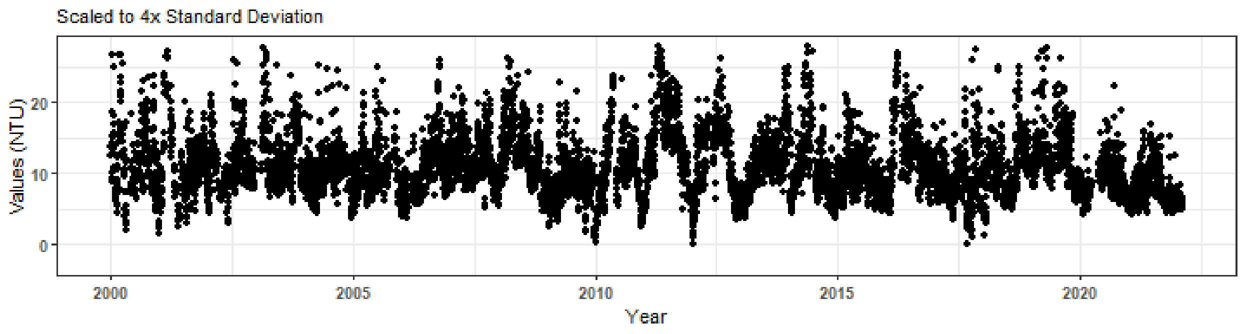




Data Points with Trendlines for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbmbwq

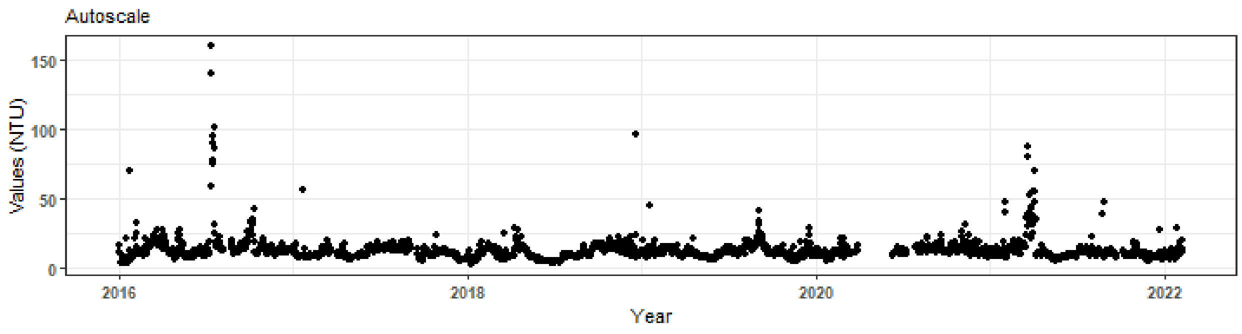
Senn Slope = -0.0920138888888888,   Senn Intercept = 219.111849937343
Trend = -1,   tau = -0.0966,   p = 0
Linear Trendline: y = -0.140821266927841x + 294.761797914514

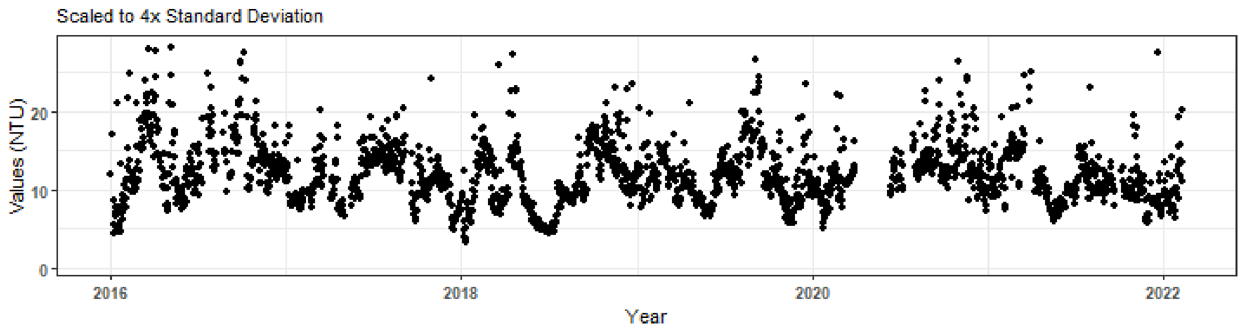


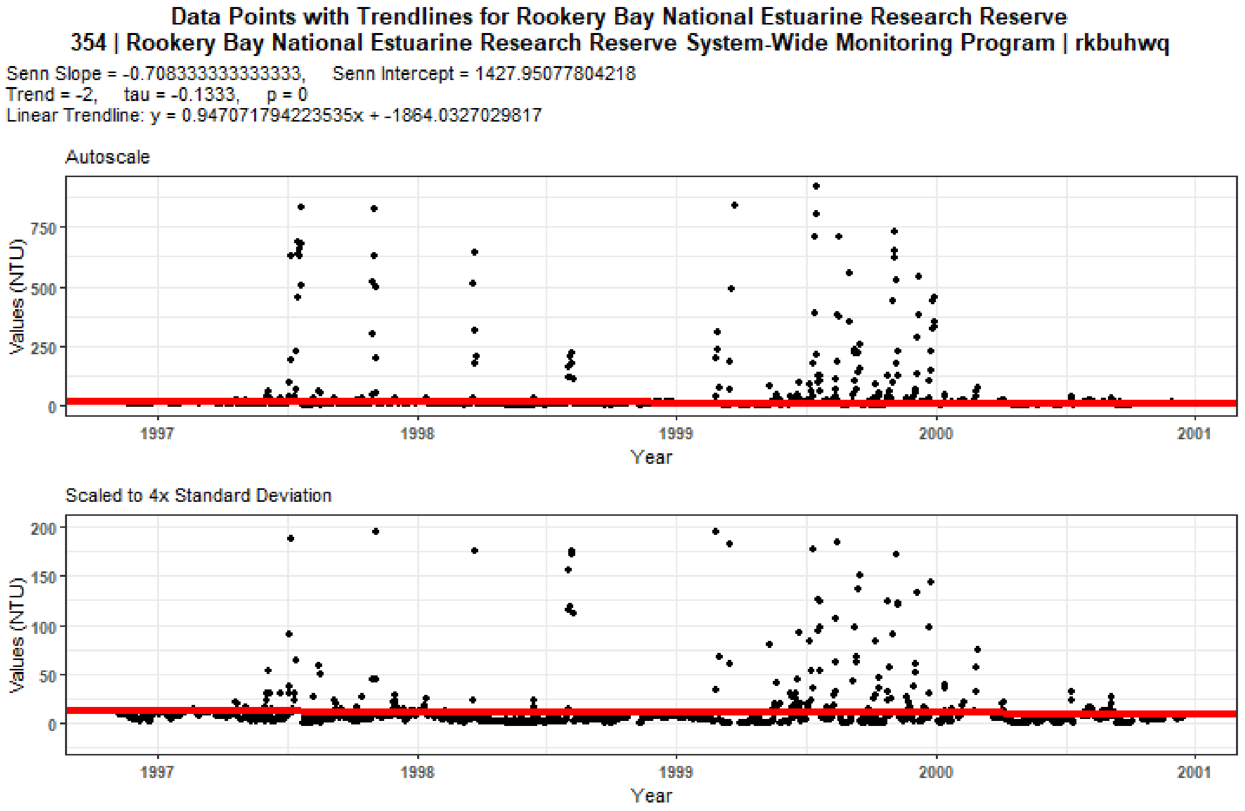


Data Points with Trendlines for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbpbwq

Senn Slope = -0.241522606382979,   Senn Intercept = 747.842859100878
Trend = -1,   tau = -0.0837,   p = 0
Linear Trendline: y = -0.380309781089862x + 780.858686876527







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:

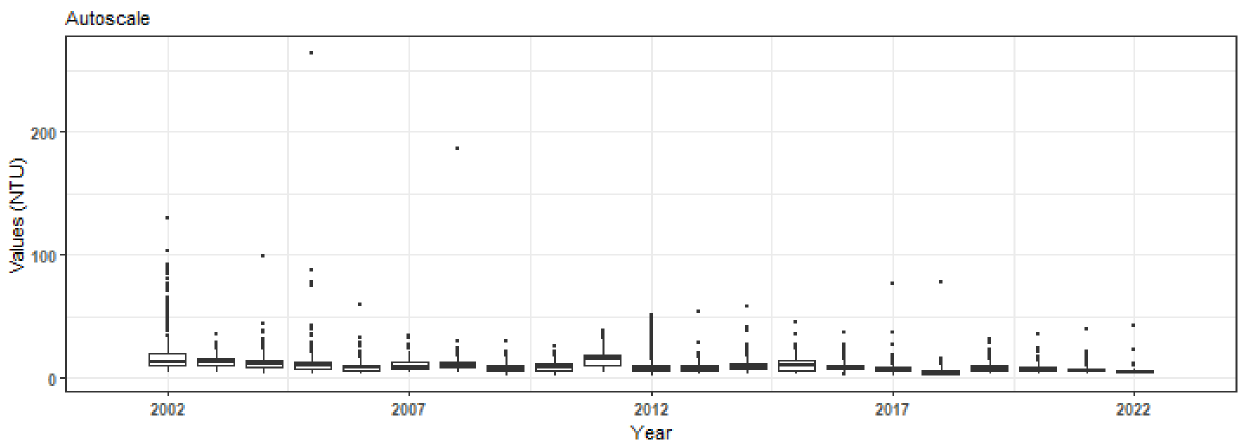
1. Y-axis autoscaled
2. Y-axis set to be mean + 4 times the standard deviation
3. Y-axis set to be mean + 4 times the standard deviation for most recent 10 years of data

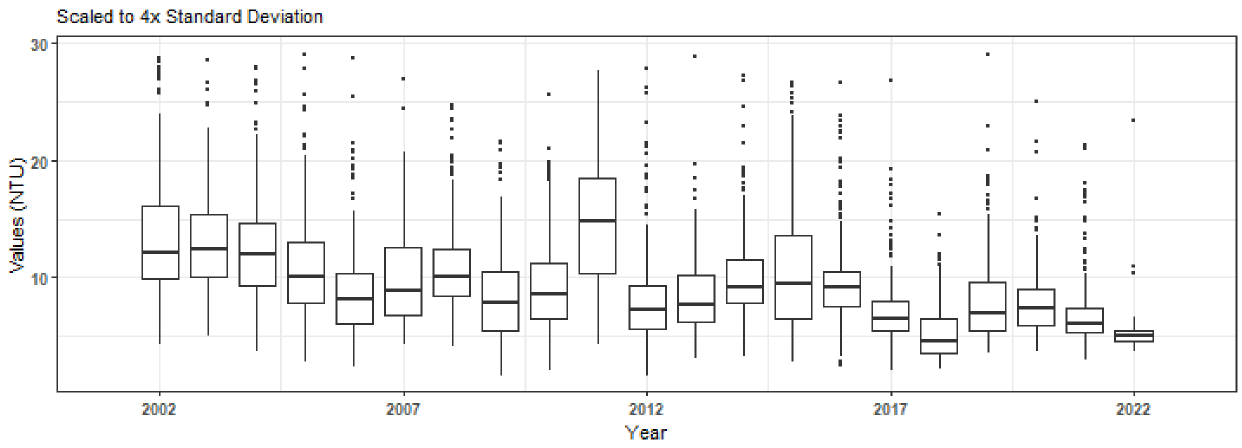
```r
if(n==0){
   print("There are no monitoring locations that qualify.")
} else {
   for (i in 1:n) {
      year_lower <- min(data$Year[data$Use_In_Analysis == TRUE &
                                  data$MonitoringID == Mon_IDs[i]])
      year_upper <- max(data$Year[data$Use_In_Analysis == TRUE &
                                  data$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(outlier.size = 0.5) +
         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))) +
         theme_bw() +
         theme(axis.text.x = element_text(face = "bold"),
               axis.text.y = element_text(face = "bold"))

      p2 <- ggplot(data = data[data$Use_In_Analysis == TRUE &
                               data$MonitoringID == Mon_IDs[i], ],
                   aes(x = Year, y = ResultValue, group = Year)) +
         geom_boxplot(outlier.size = 0.5) +
         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))) +
         theme_bw() +
         theme(axis.text.x = element_text(face = "bold"),
               axis.text.y = element_text(face = "bold"))
```

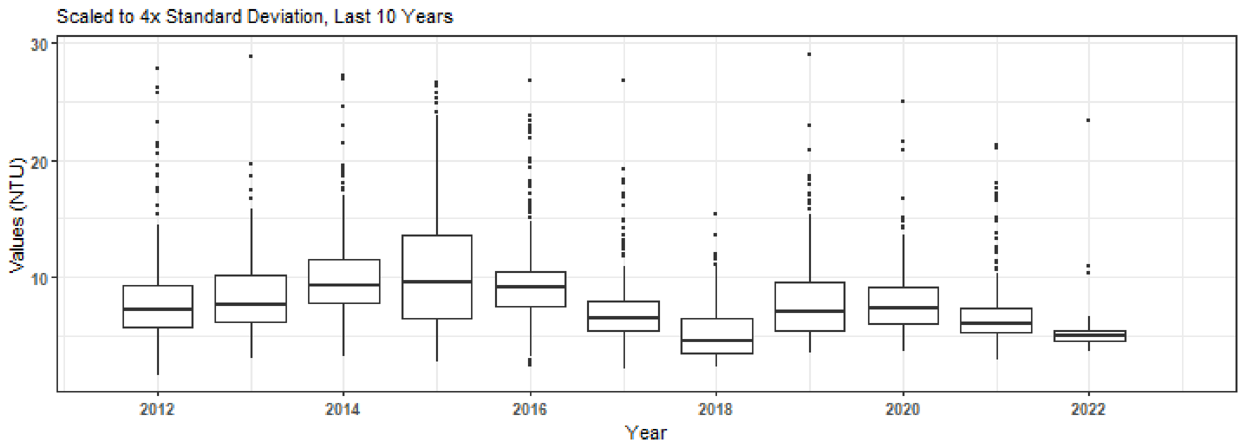
```r
p3 <- ggplot(data = data[data$Use_In_Analysis == TRUE &
                            data$MonitoringID == Mon_IDs[i] &
                            data$Year>=year_upper-10, ],
             aes(x = Year, y = ResultValue, group = Year)) +
   geom_boxplot(outlier.size = 0.5) +
   labs(subtitle = "Scaled 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))) +
   theme_bw() +
   theme(axis.text.x = element_text(face = "bold"),
         axis.text.y = element_text(face = "bold"))

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

p0 <- ggplot() + labs(title = paste0("Summary Box Plots for ",
                                     MA_name, "\n", Mon_name),
                      subtitle = "By Year") +
   theme_bw() + theme(plot.title = element_text(face="bold", hjust=0.5),
         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(outlier.size = 0.5) +
   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))) +
   theme_bw() +
   theme(legend.position = "none",
         axis.text.x = element_text(face = "bold"),
         axis.text.y = element_text(face = "bold"))

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(outlier.size = 0.5) +
   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))) +
   theme_bw() +
  theme(legend.position = "top", legend.box = "horizontal",
        axis.text.x = element_text(face = "bold"),
        axis.text.y = element_text(face = "bold")) +
  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(outlier.size = 0.5) +
  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))) +
  theme_bw() +
  theme(legend.position = "none",
        axis.text.x = element_text(face = "bold"),
        axis.text.y = element_text(face = "bold"))

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") + theme_bw() +
  theme(plot.title = element_text(face="bold", hjust=0.5),
        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(outlier.size = 0.5) +
  labs(subtitle = "Autoscale",
       x = "Month", y = paste0("Values (", unit, ")"), fill = "Month") +
  scale_x_continuous(limits = c(0, 13), breaks = seq(3, 12, 3)) +
  theme_bw() +
  theme(legend.position = "none",
        axis.text.x = element_text(face = "bold"),
        axis.text.y = element_text(face = "bold"))

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(outlier.size = 0.5) +
  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)) +
        theme_bw() +
        theme(legend.position = "top", legend.box = "horizontal",
              axis.text.x = element_text(face = "bold"),
              axis.text.y = element_text(face = "bold")) +
        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(outlier.size = 0.5) +
        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)) +
        theme_bw() +
        theme(legend.position = "none",
              axis.text.x = element_text(face = "bold"),
              axis.text.y = element_text(face = "bold"))

      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") + theme_bw() +
        theme(plot.title = element_text(face="bold", hjust=0.5),
              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)))
   }
}
```

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

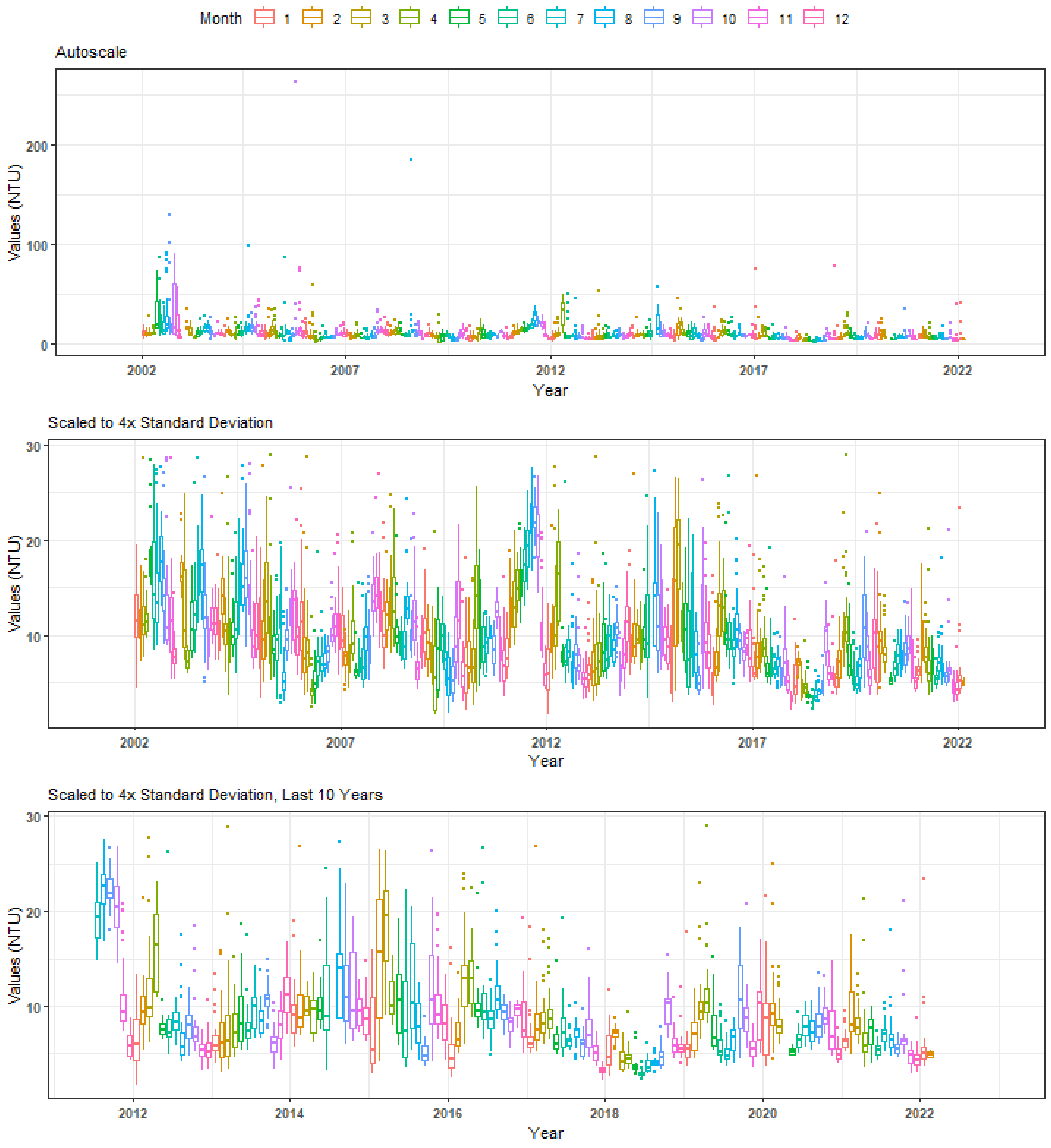






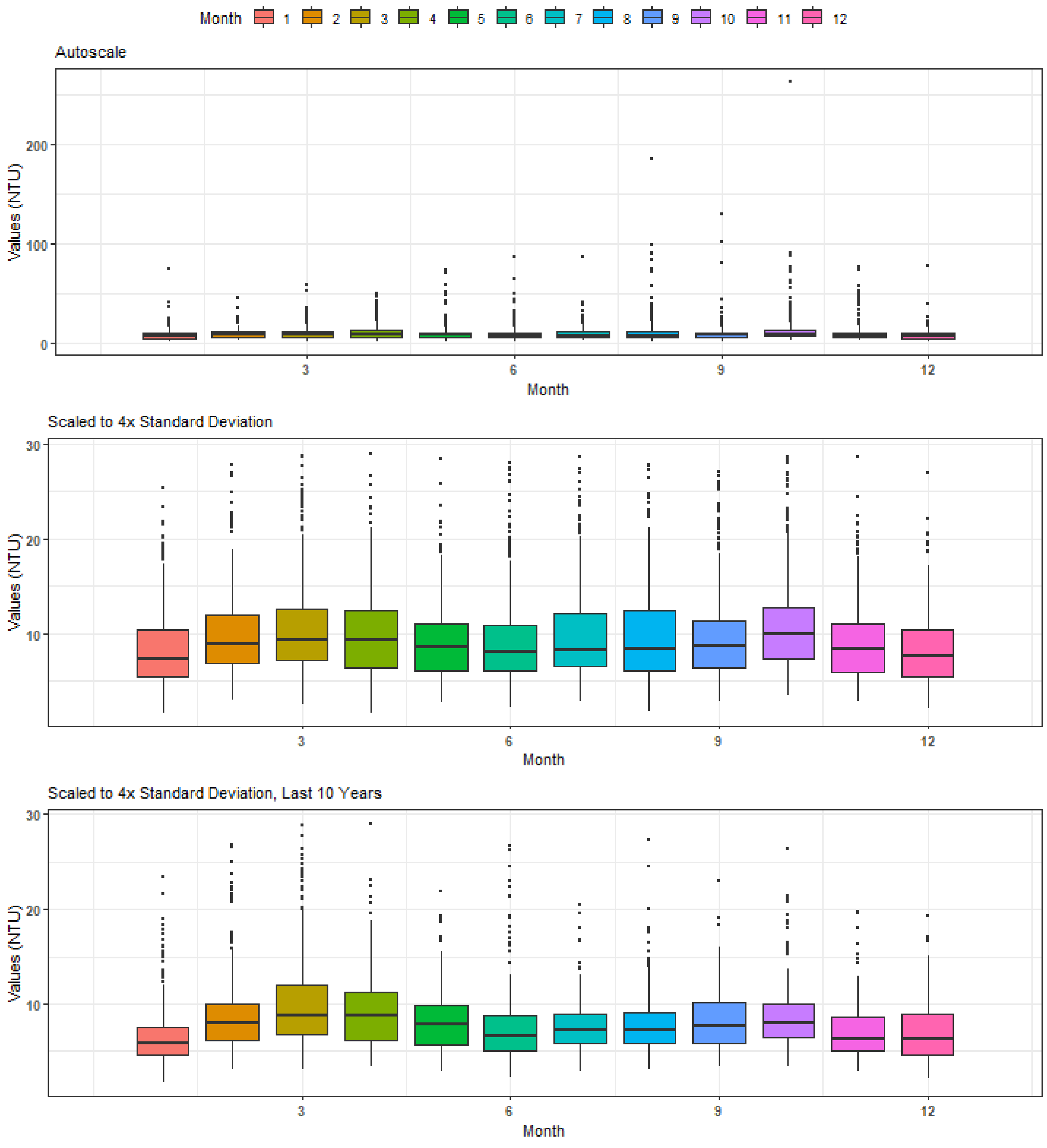
Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfbwq

By Year & Month



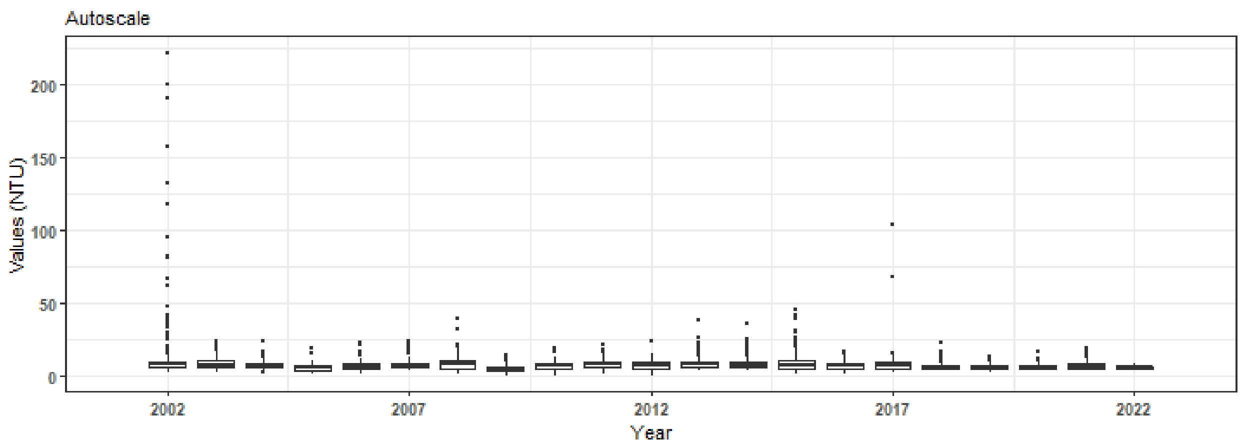
Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfbwq

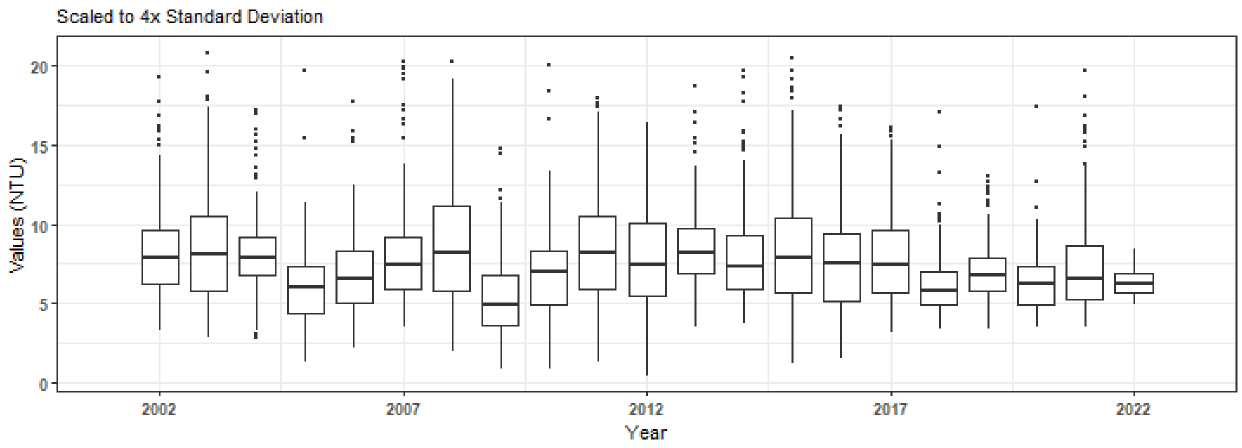
By Month

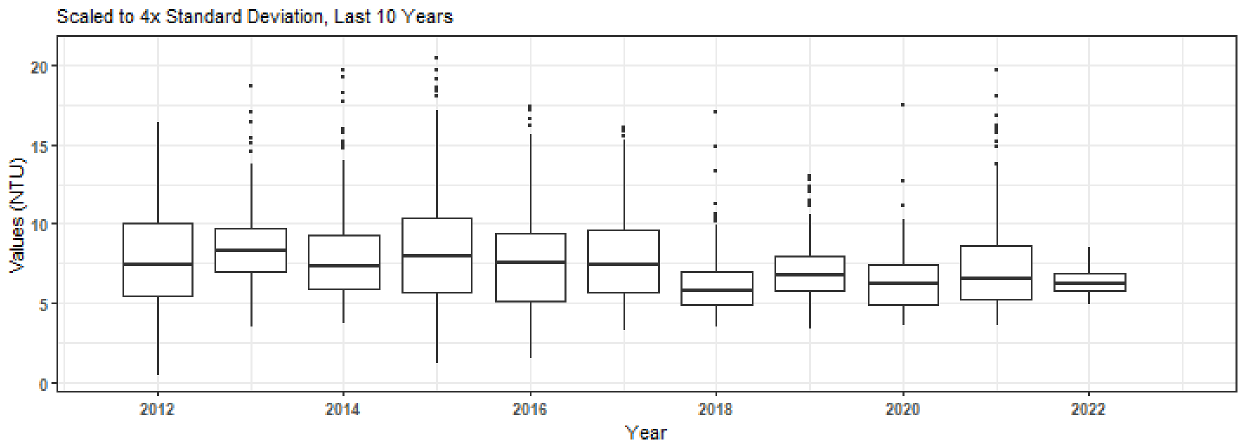


Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfuwq

By Year

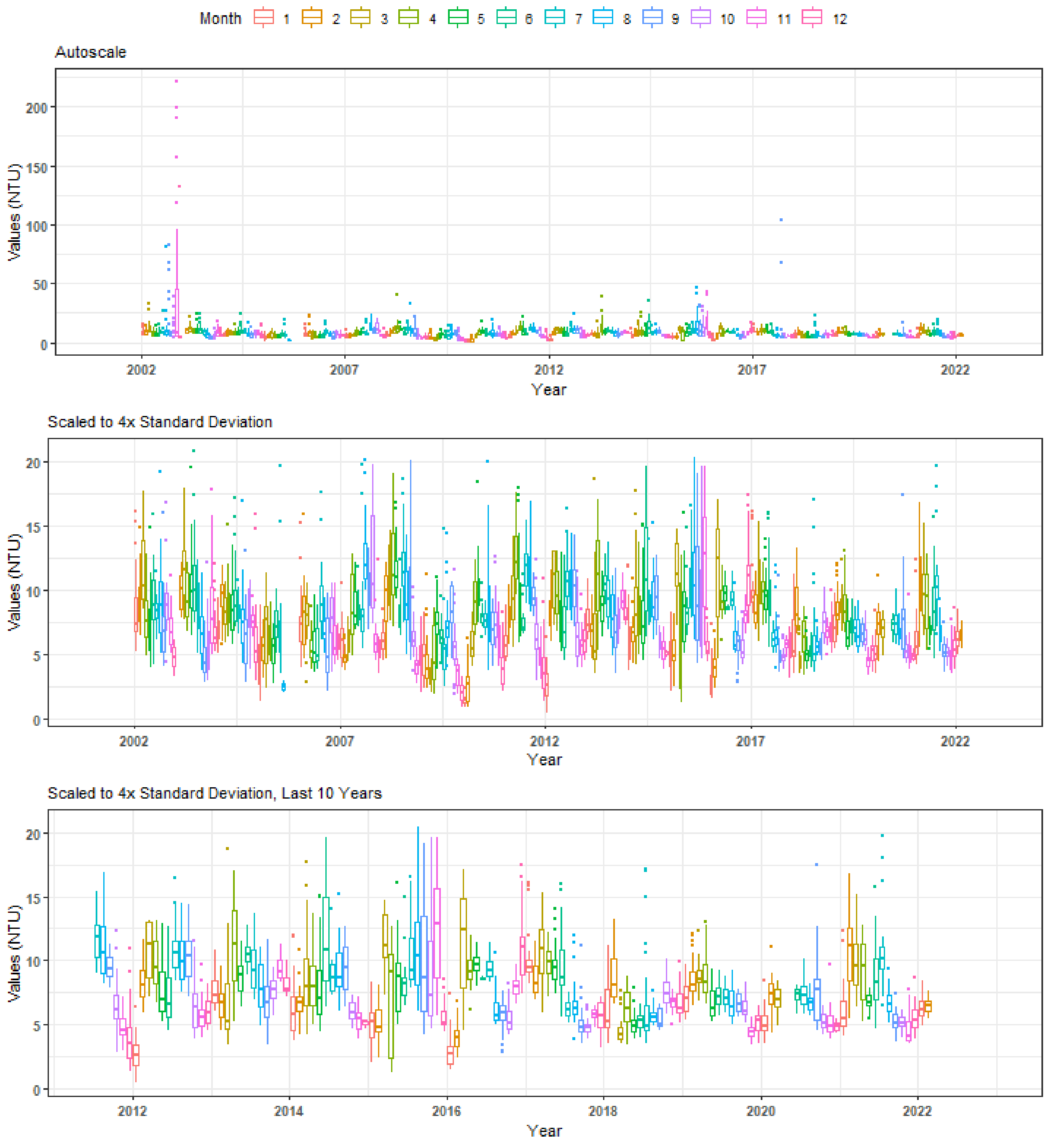






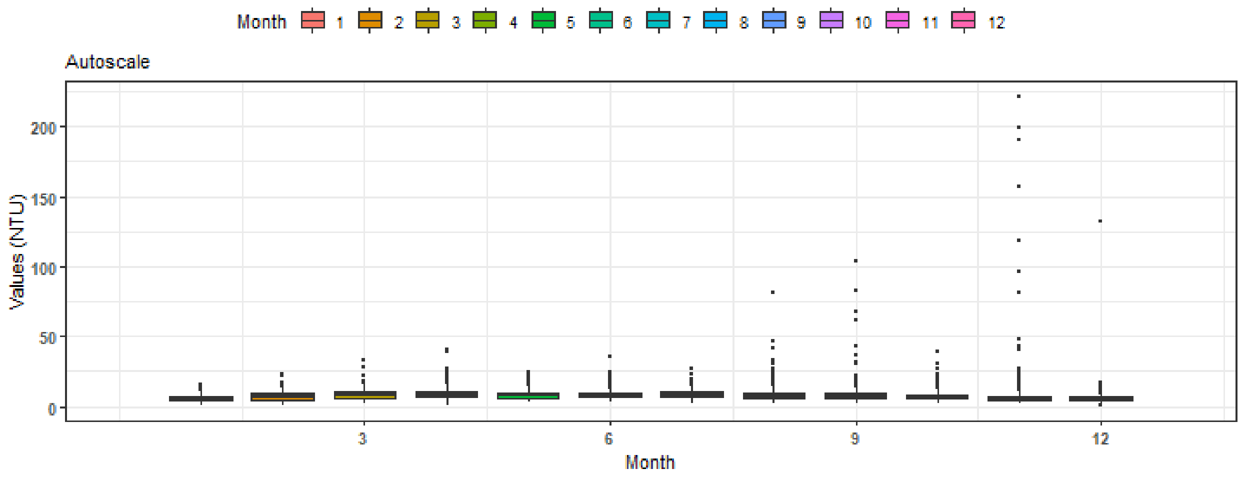
Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfuwq

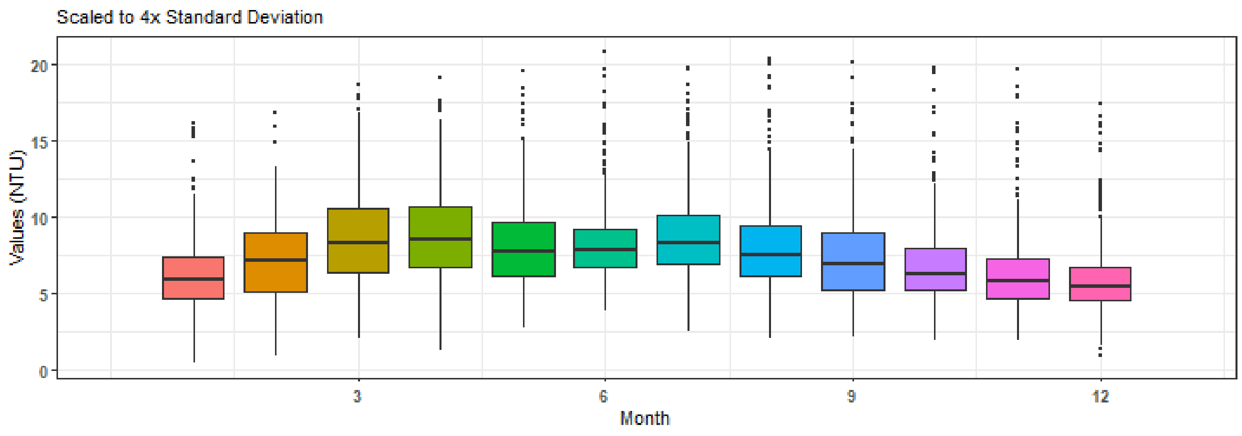
By Year & Month

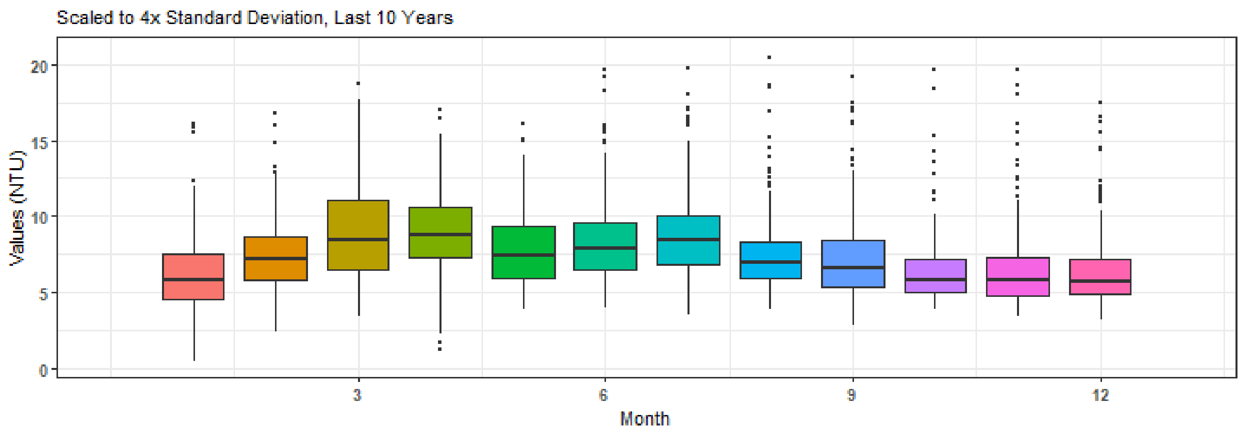


Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfuwq

By Month

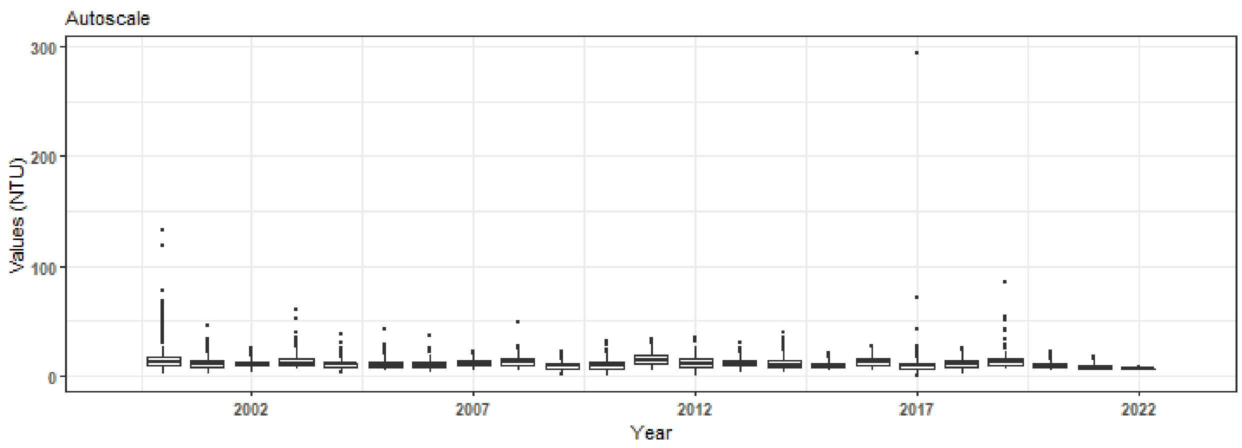


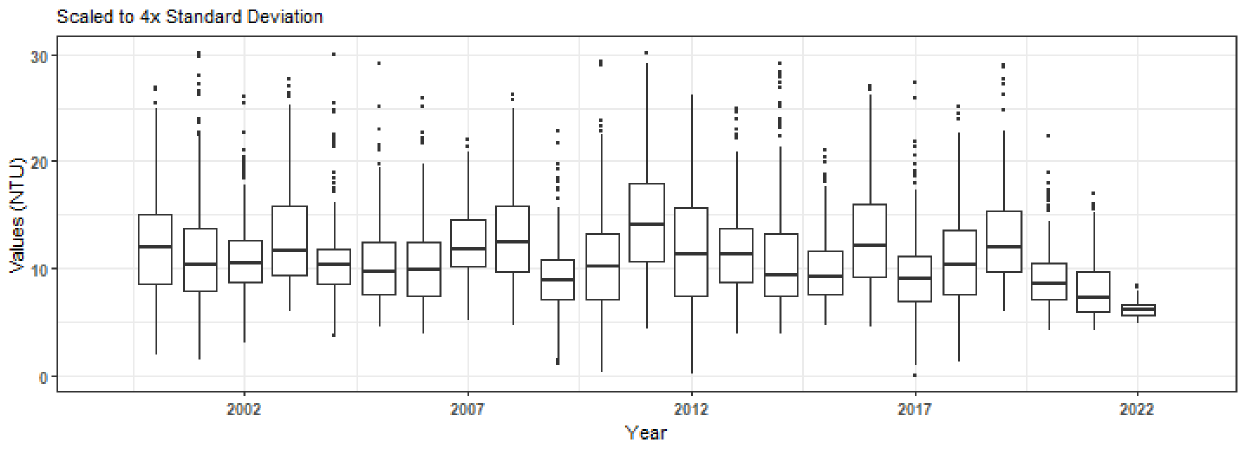


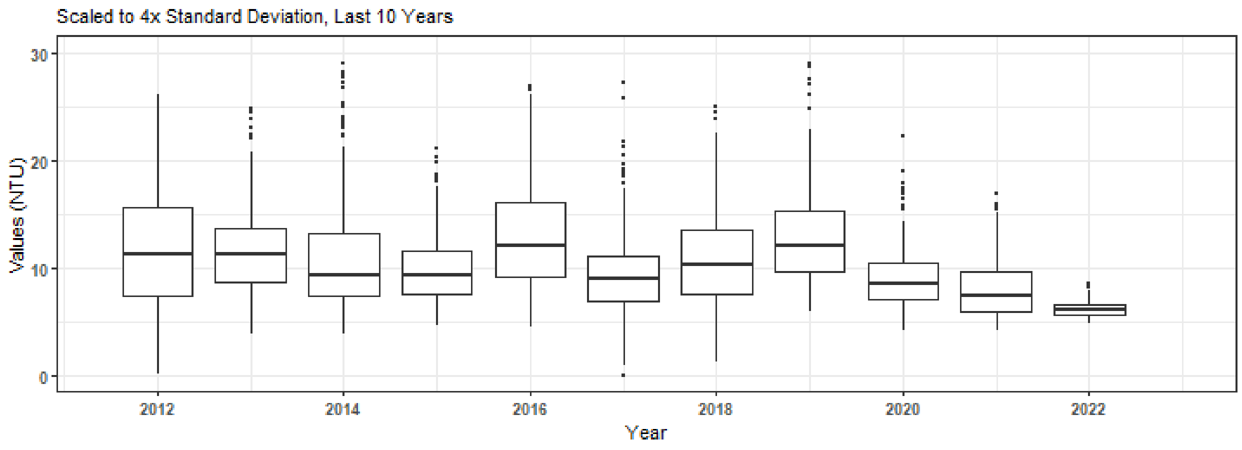


Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbmbwq

By Year

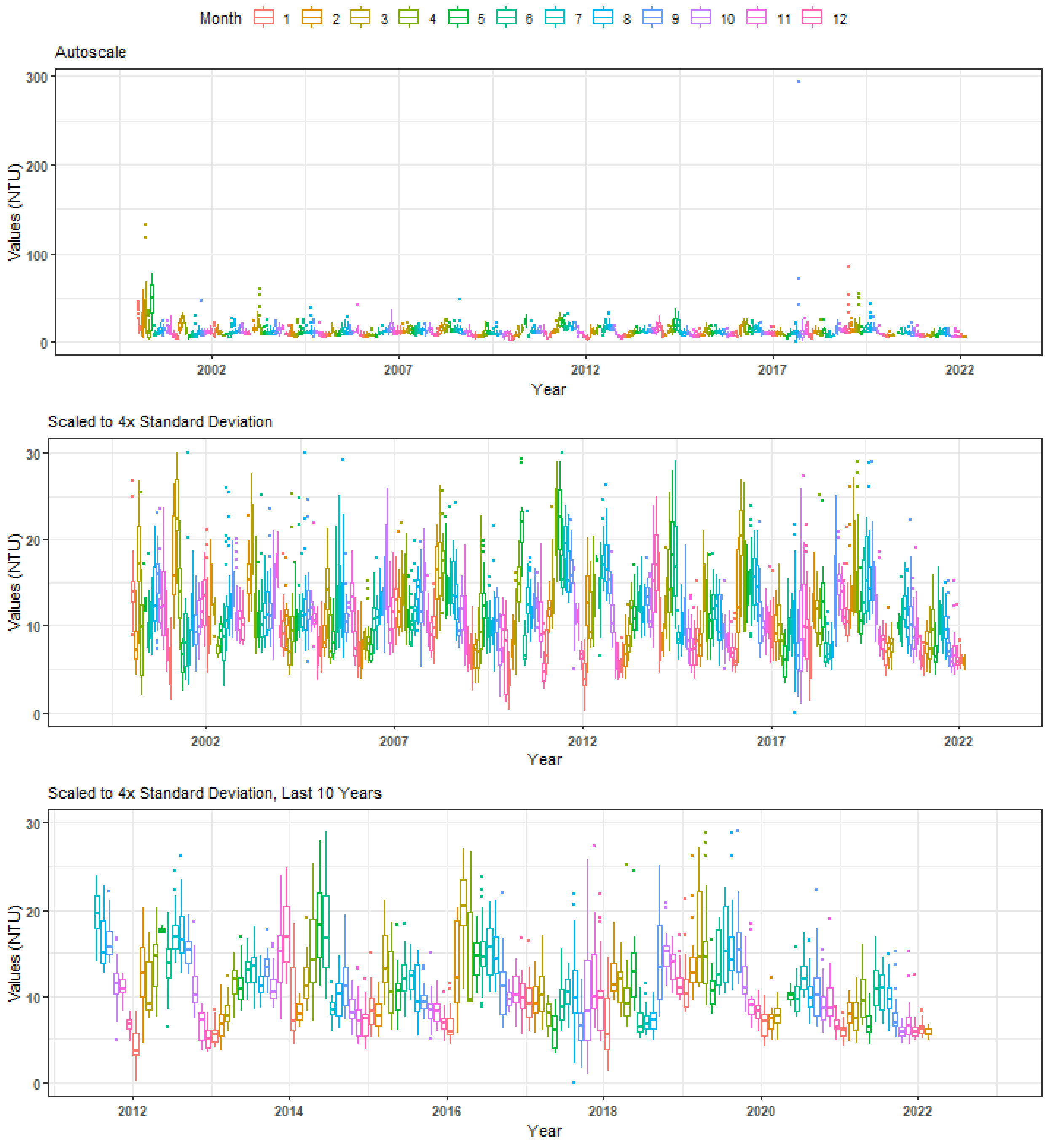






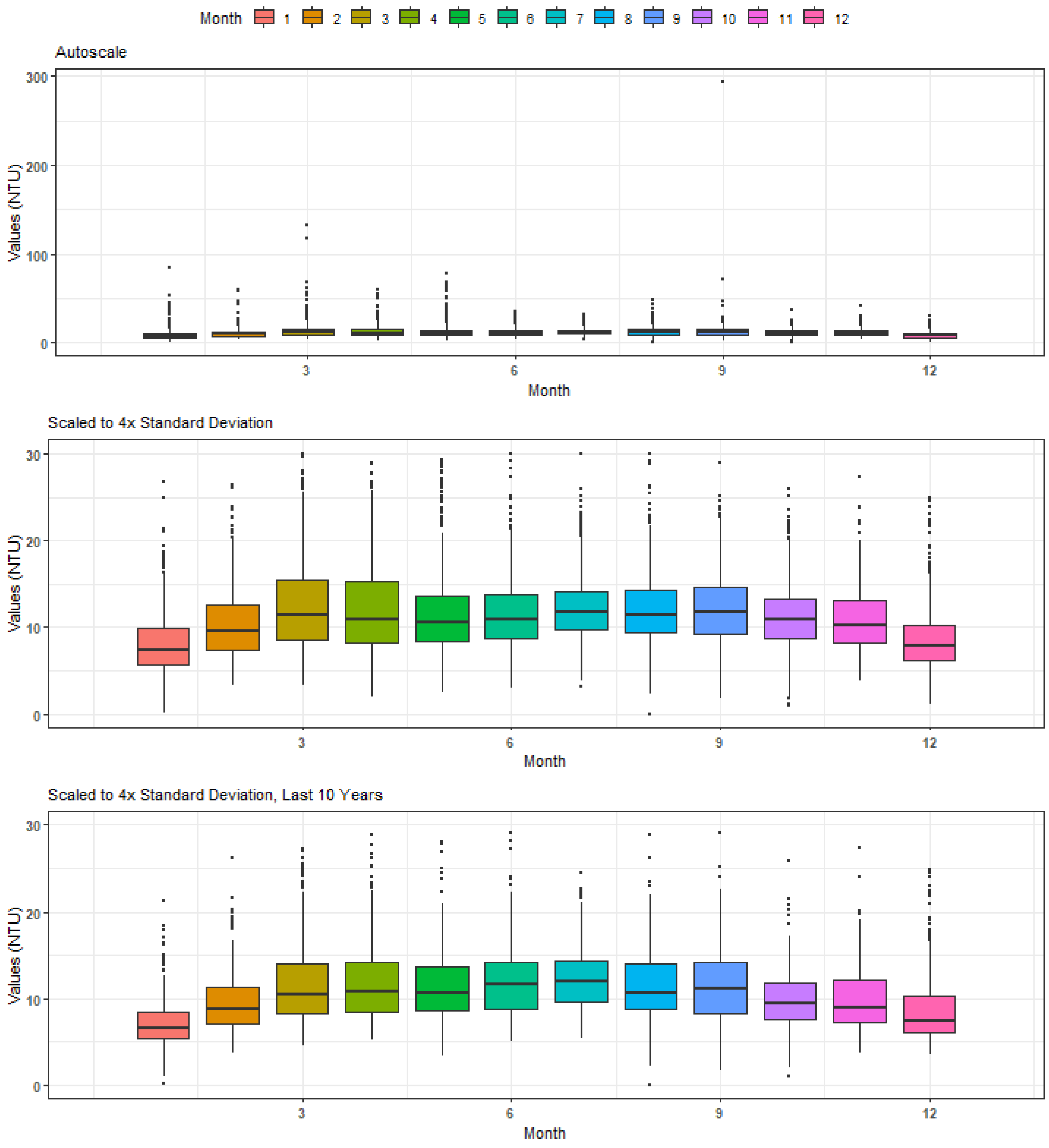
Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbmbwq

By Year & Month



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

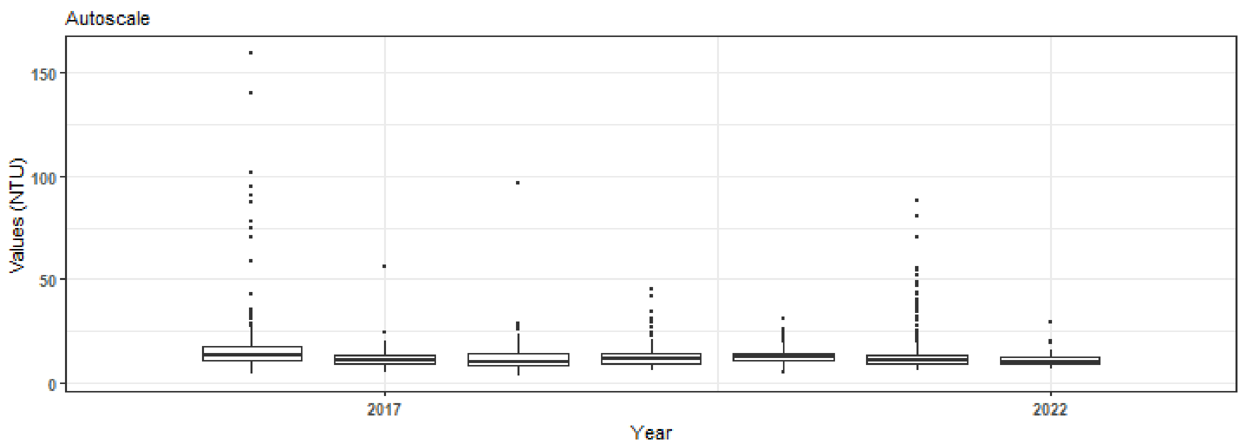
By Month



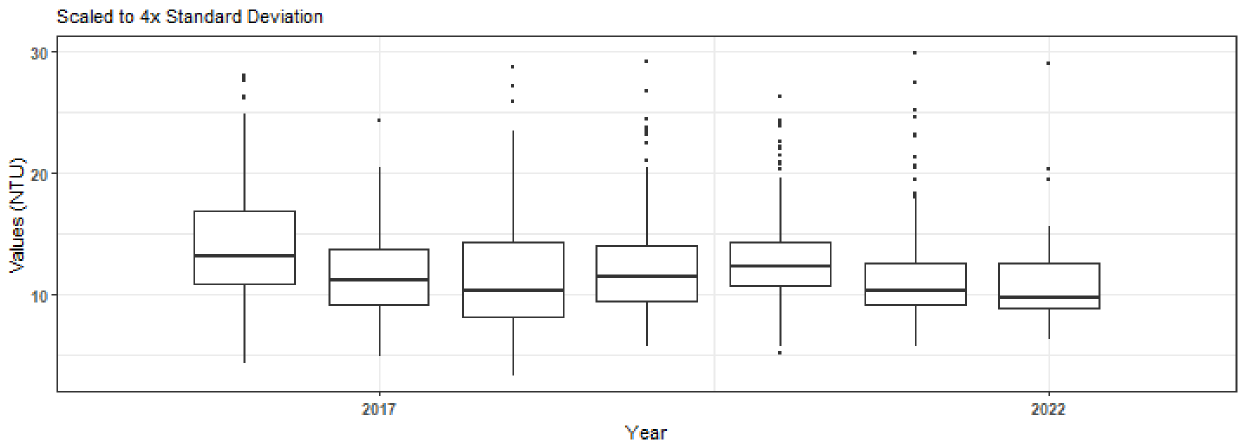
Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbpbwq

By Year

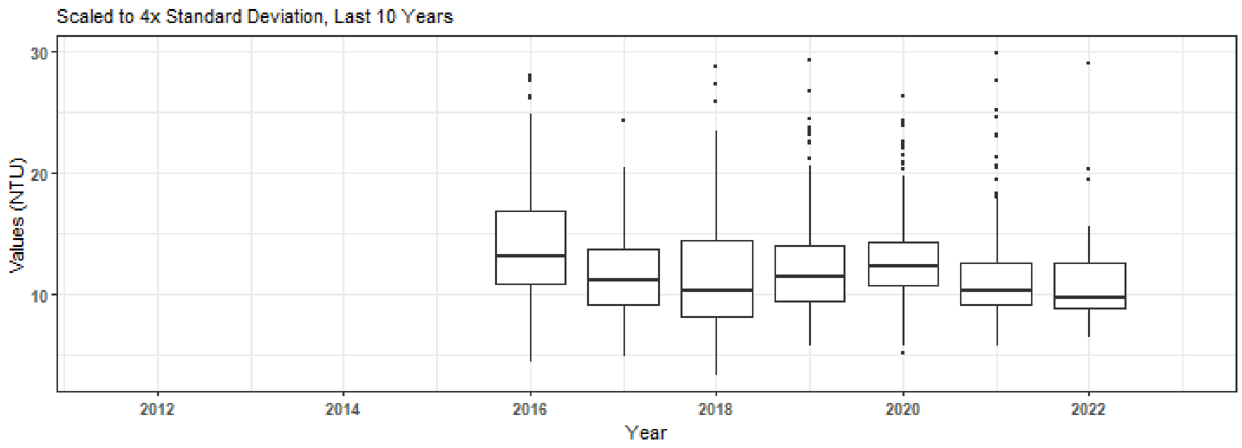
Autoscale



Scaled to 4x Standard Deviation

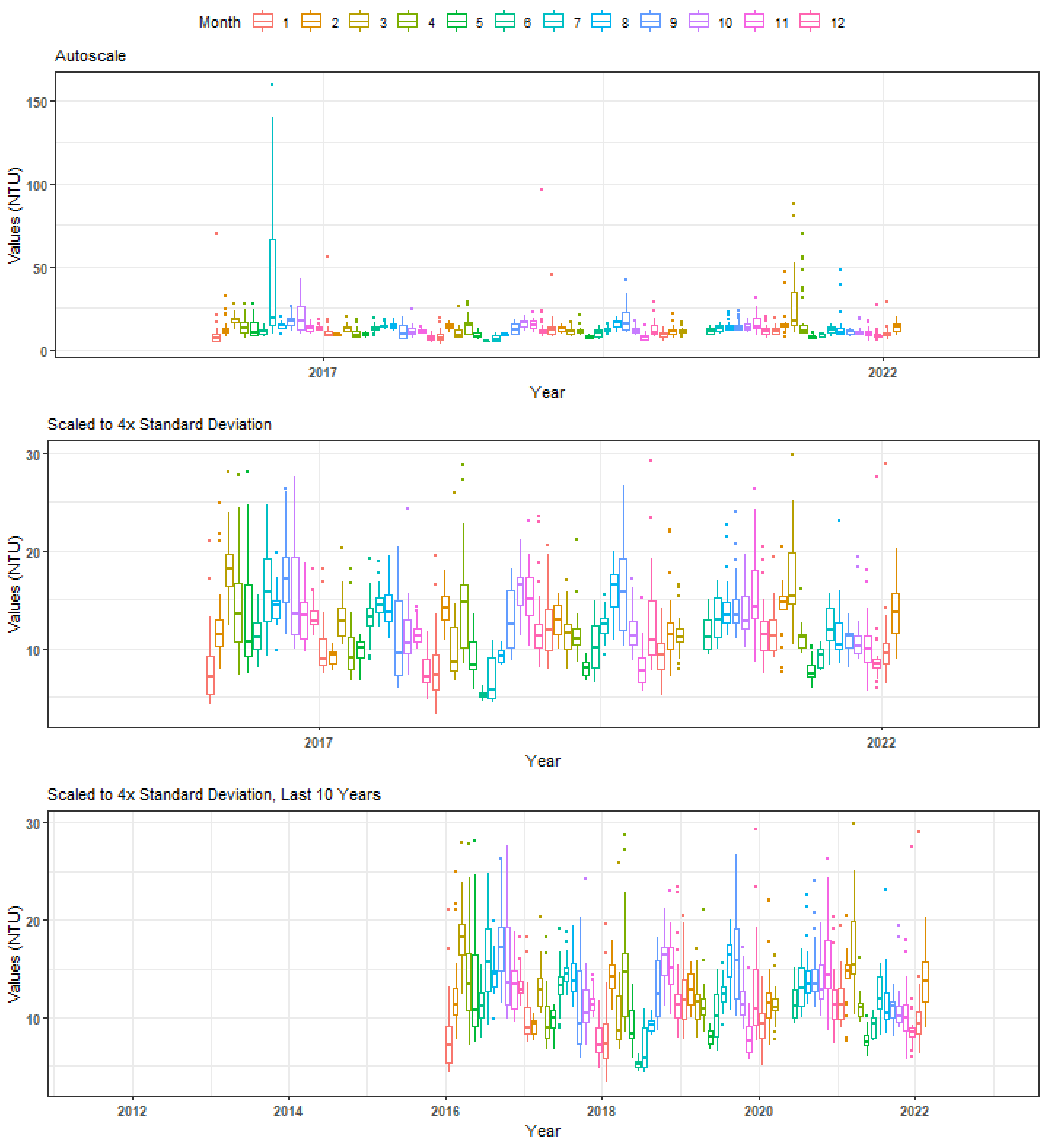


Scaled to 4x Standard Deviation, Last 10 Years



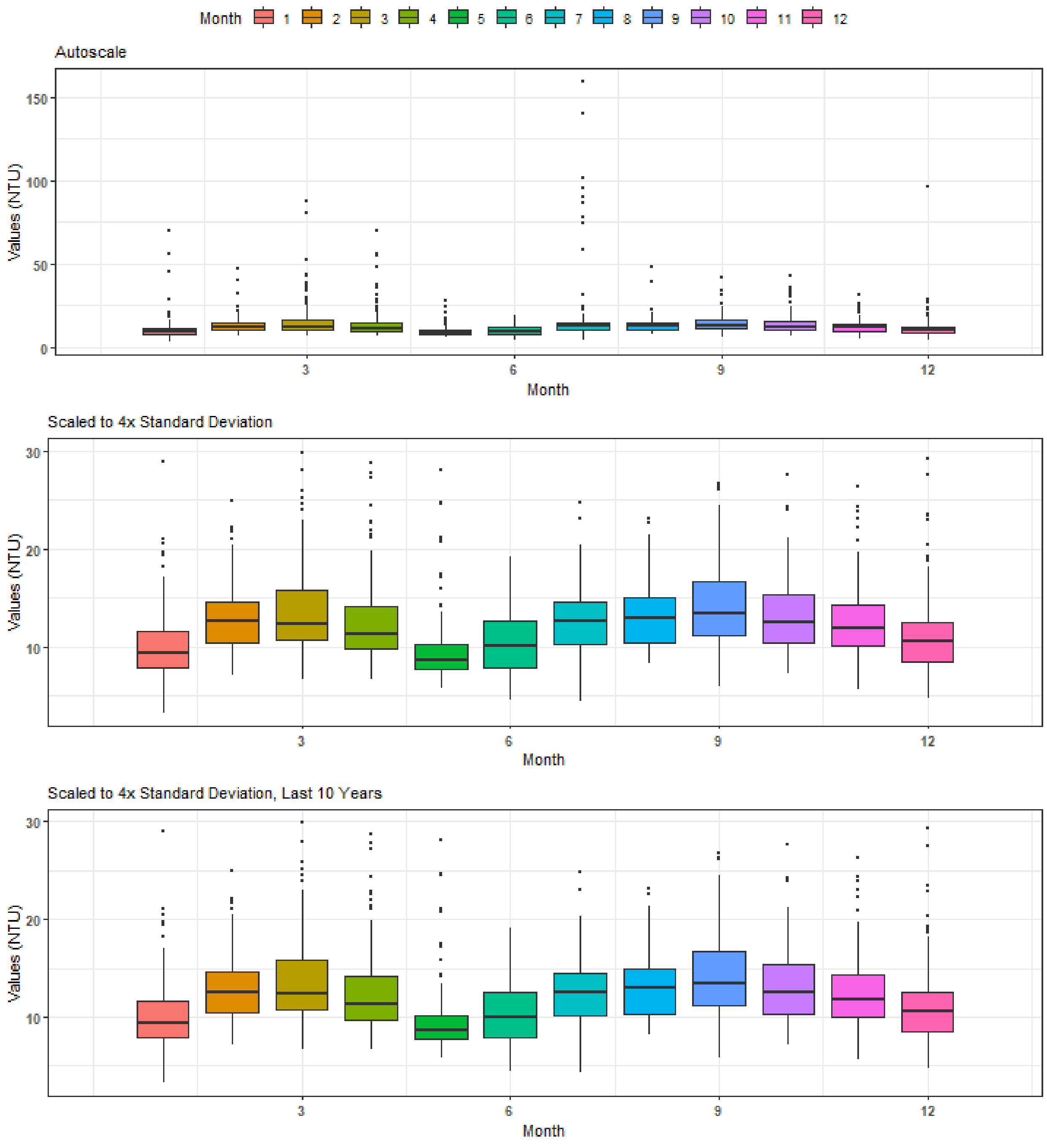
Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbpbwq

By Year & Month



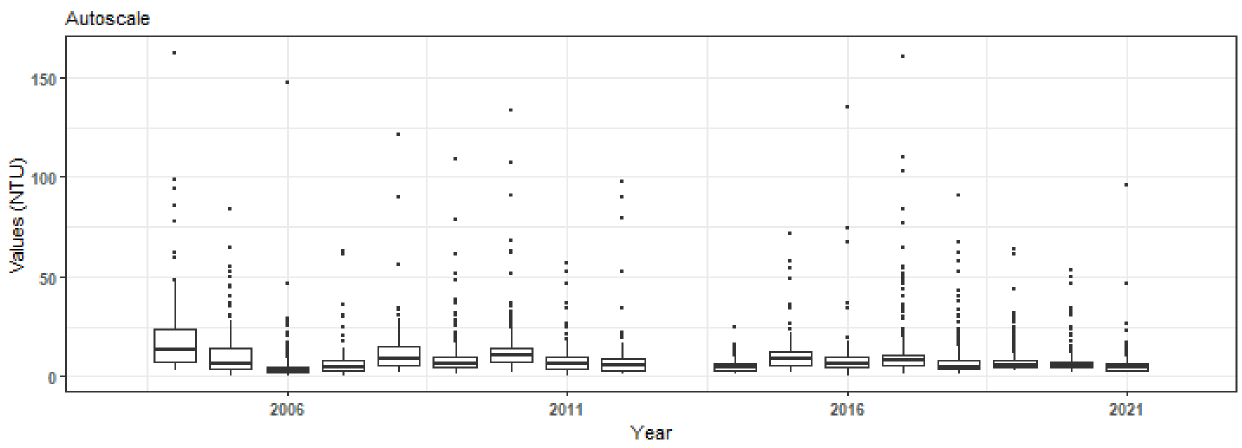
Summary Box Plots for Cape Romano-Ten Thousand Islands Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbpbwq

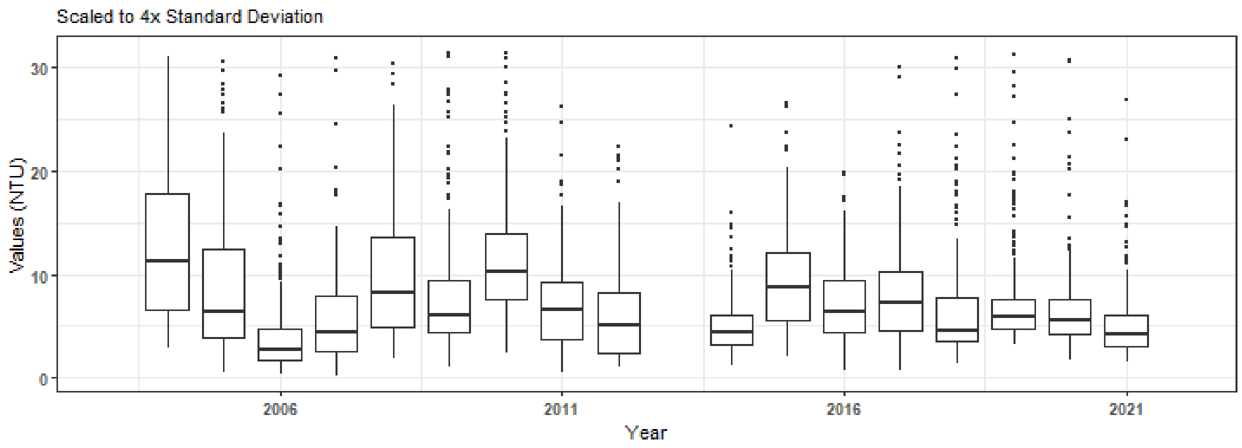
By Month

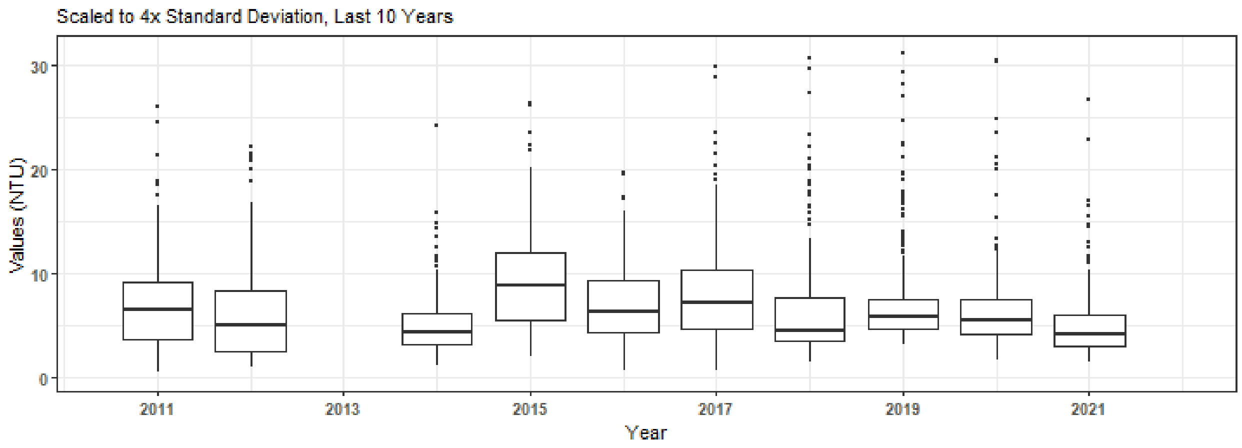


Summary Box Plots for Estero Bay Aquatic Preserve
474 | Estero Bay Aquatic Preserve Continuous Water Quality Monitoring | EB02

By Year

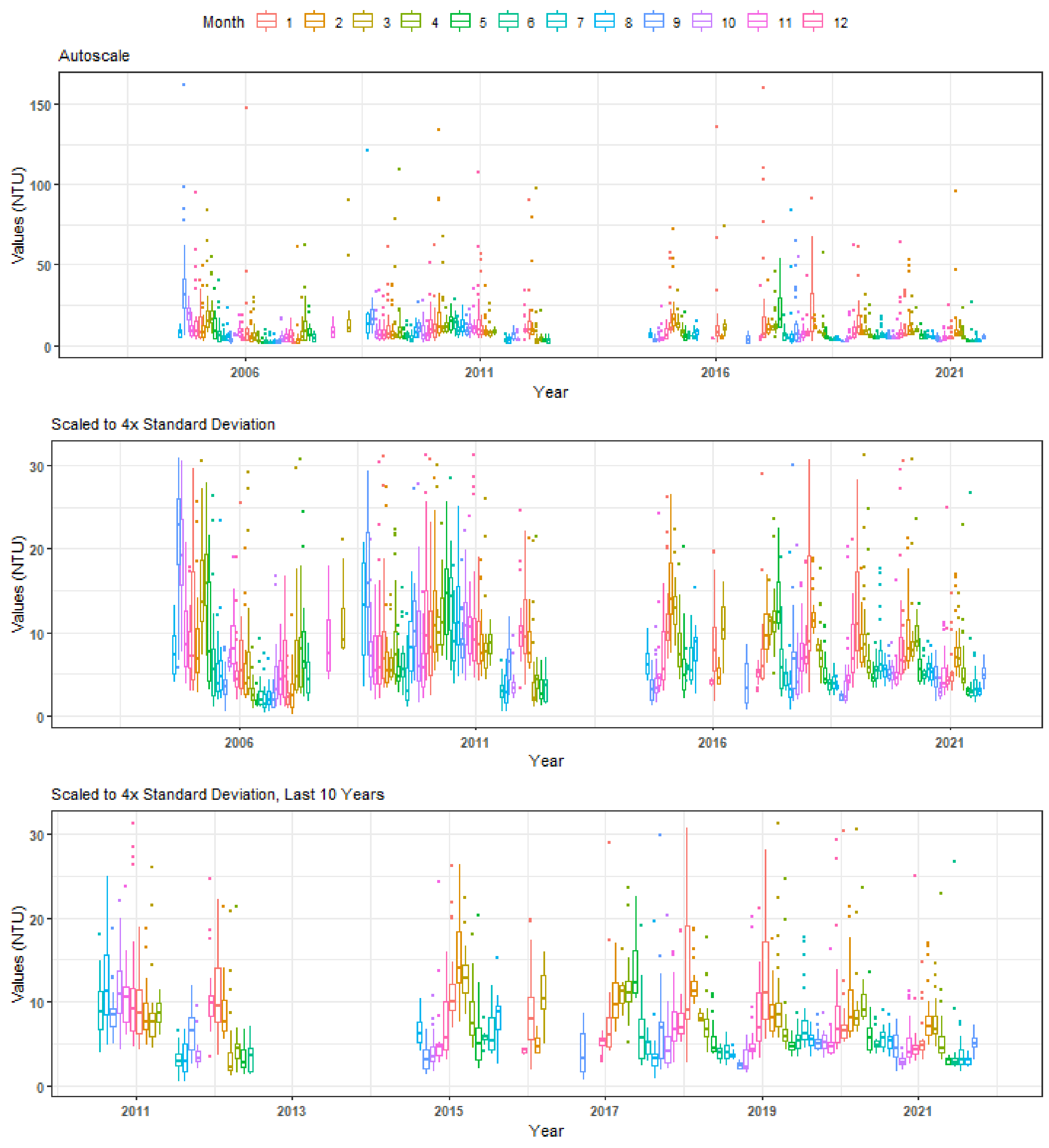






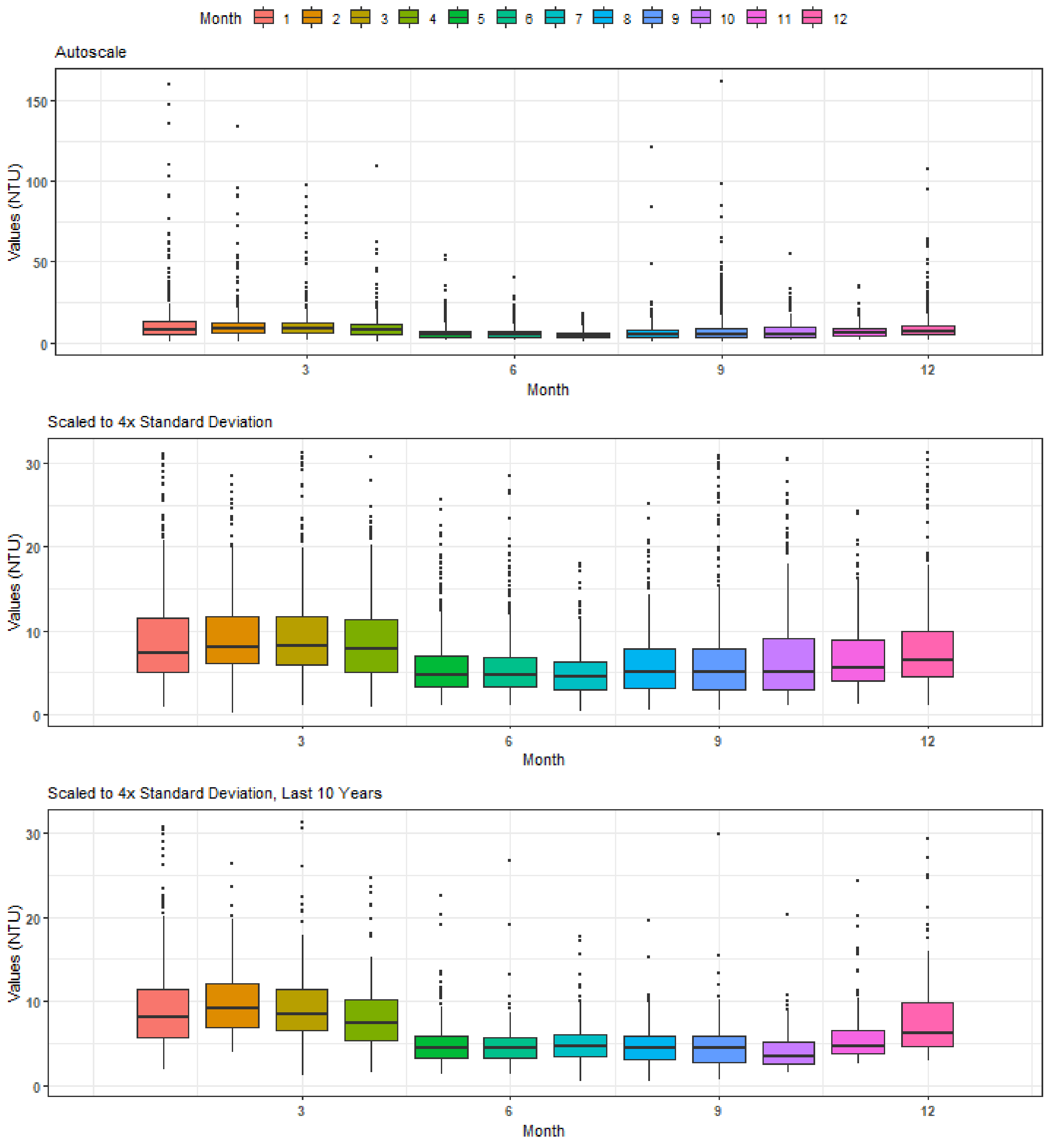
Summary Box Plots for Estero Bay Aquatic Preserve
474 | Estero Bay Aquatic Preserve Continuous Water Quality Monitoring | EB02

By Year & Month



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

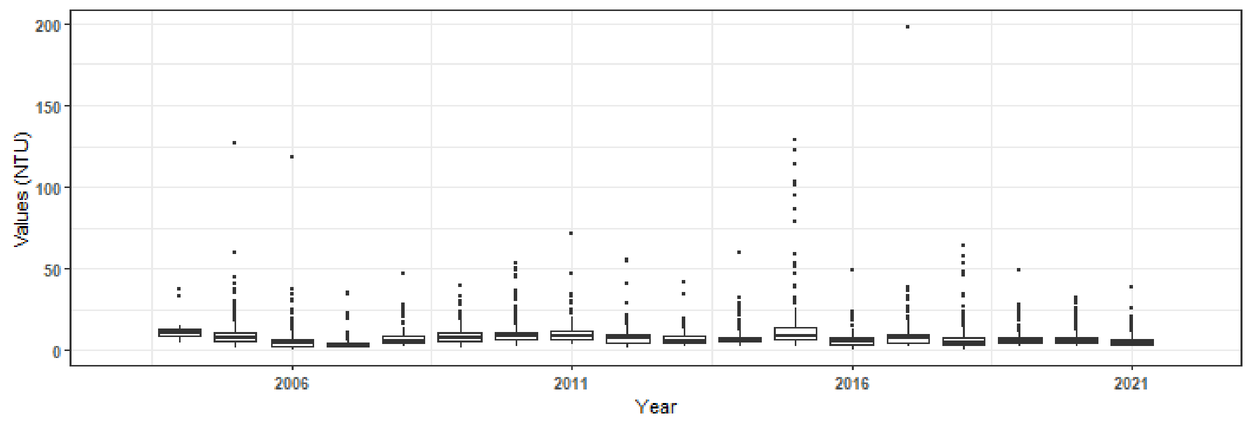
By Month



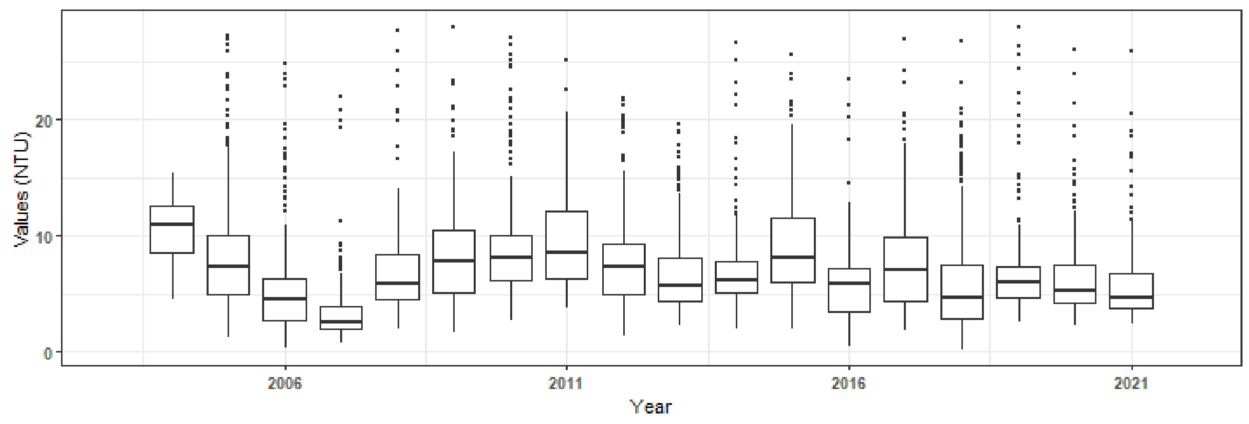
Summary Box Plots for Estero Bay Aquatic Preserve
474 | Estero Bay Aquatic Preserve Continuous Water Quality Monitoring | EB03

By Year

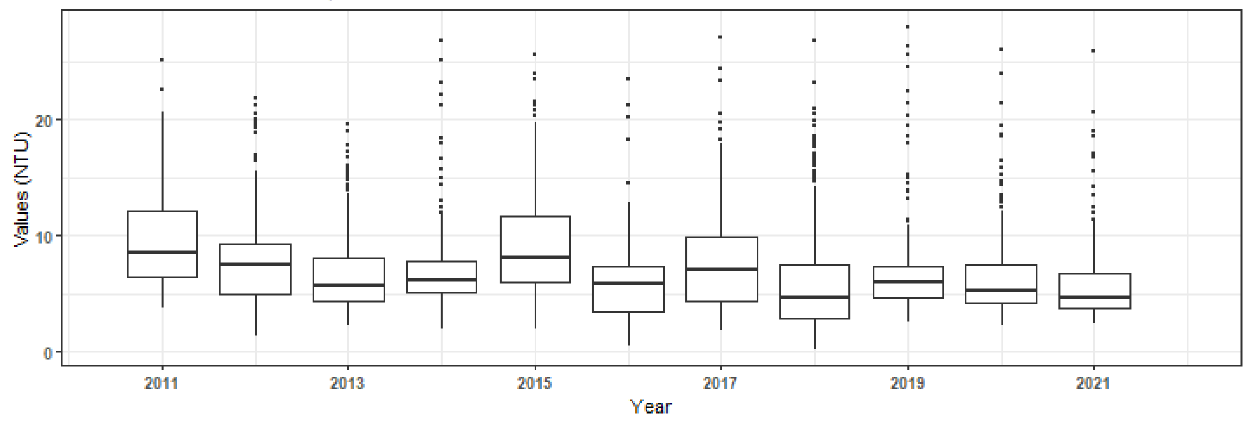
Autoscale



Scaled to 4x Standard Deviation

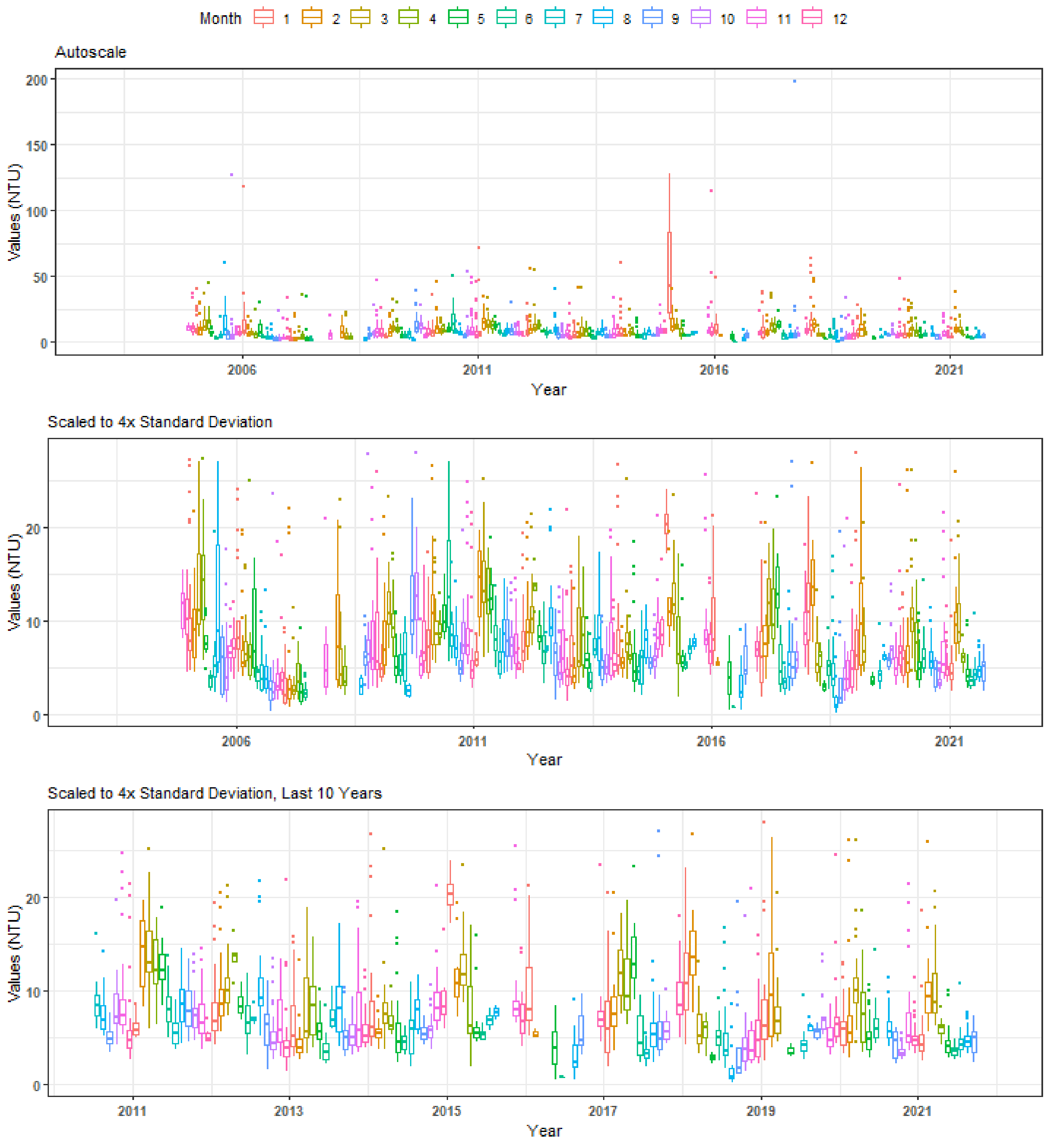


Scaled to 4x Standard Deviation, Last 10 Years



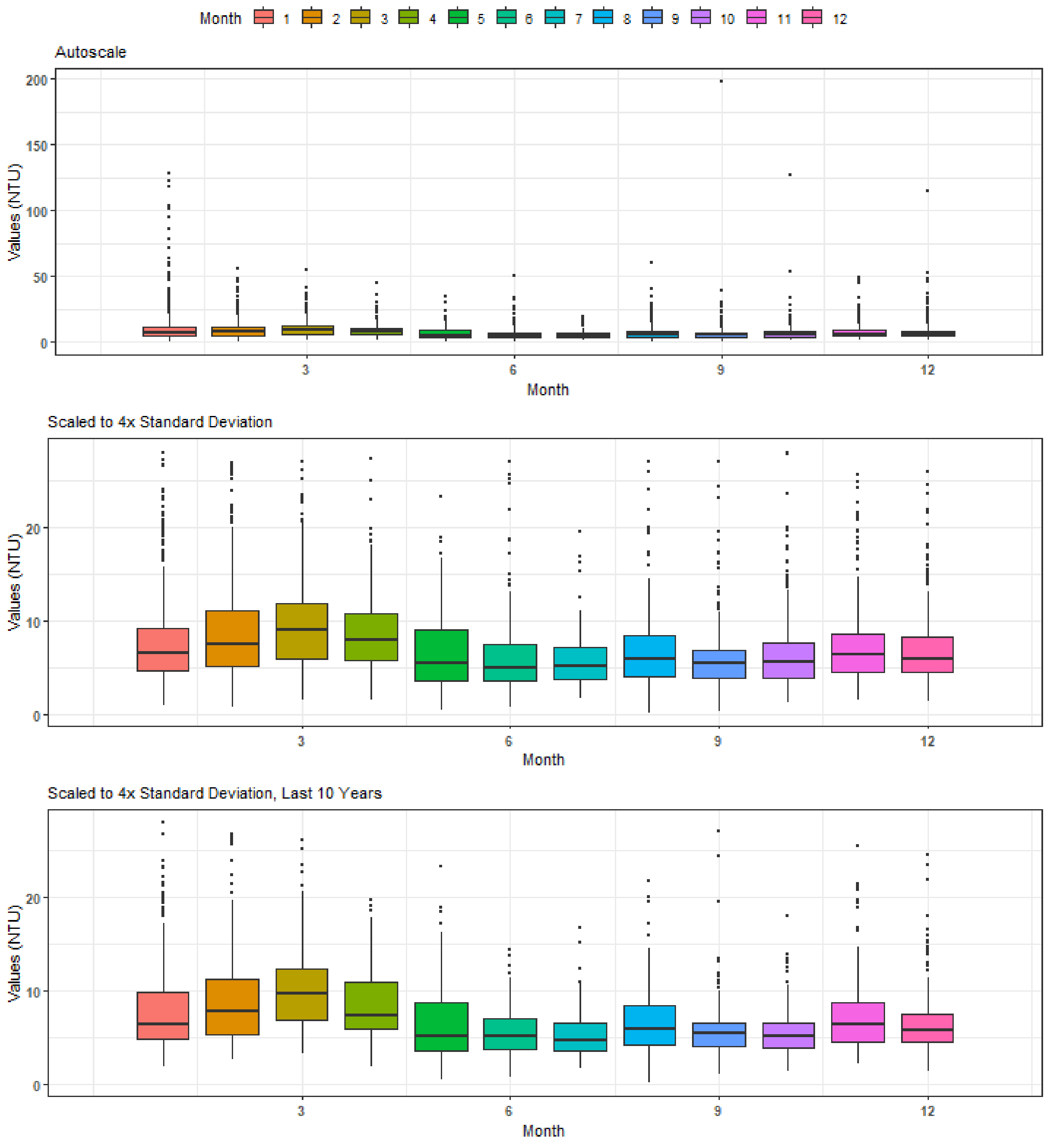
Summary Box Plots for Estero Bay Aquatic Preserve
474 | Estero Bay Aquatic Preserve Continuous Water Quality Monitoring | EB03

By Year & Month



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

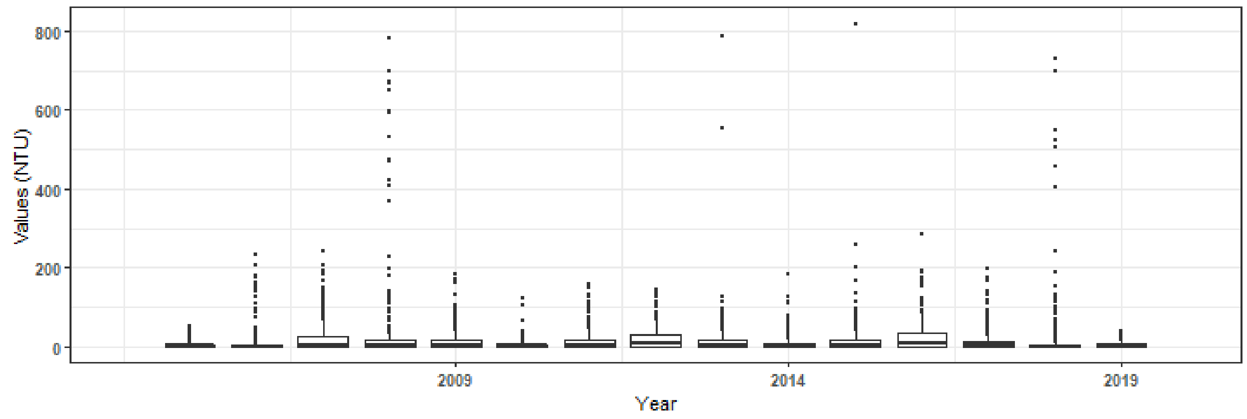
By Month



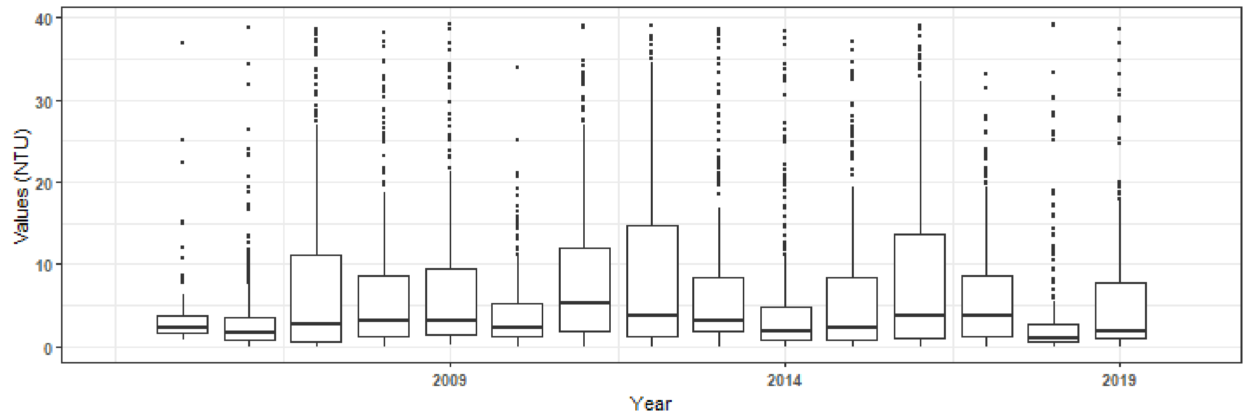
Summary Box Plots for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP1A

By Year

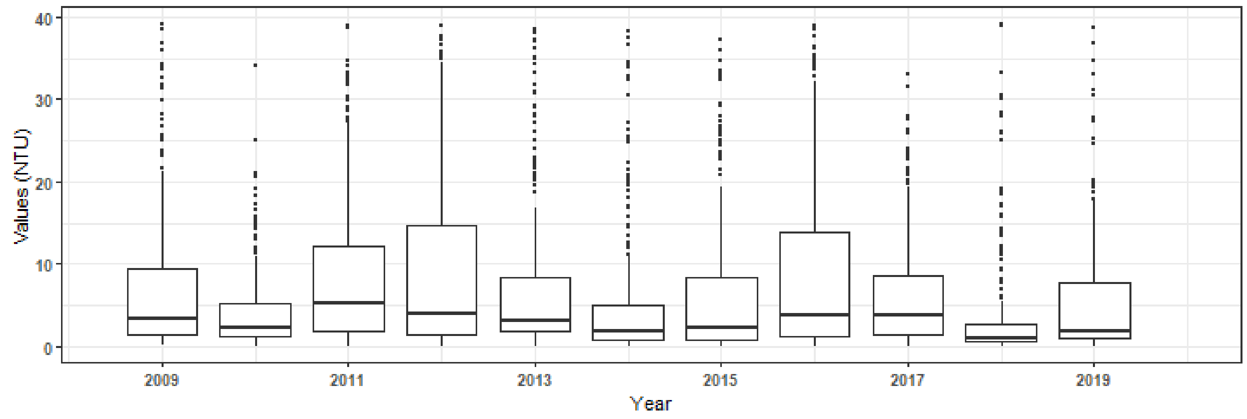
Autoscale



Scaled to 4x Standard Deviation

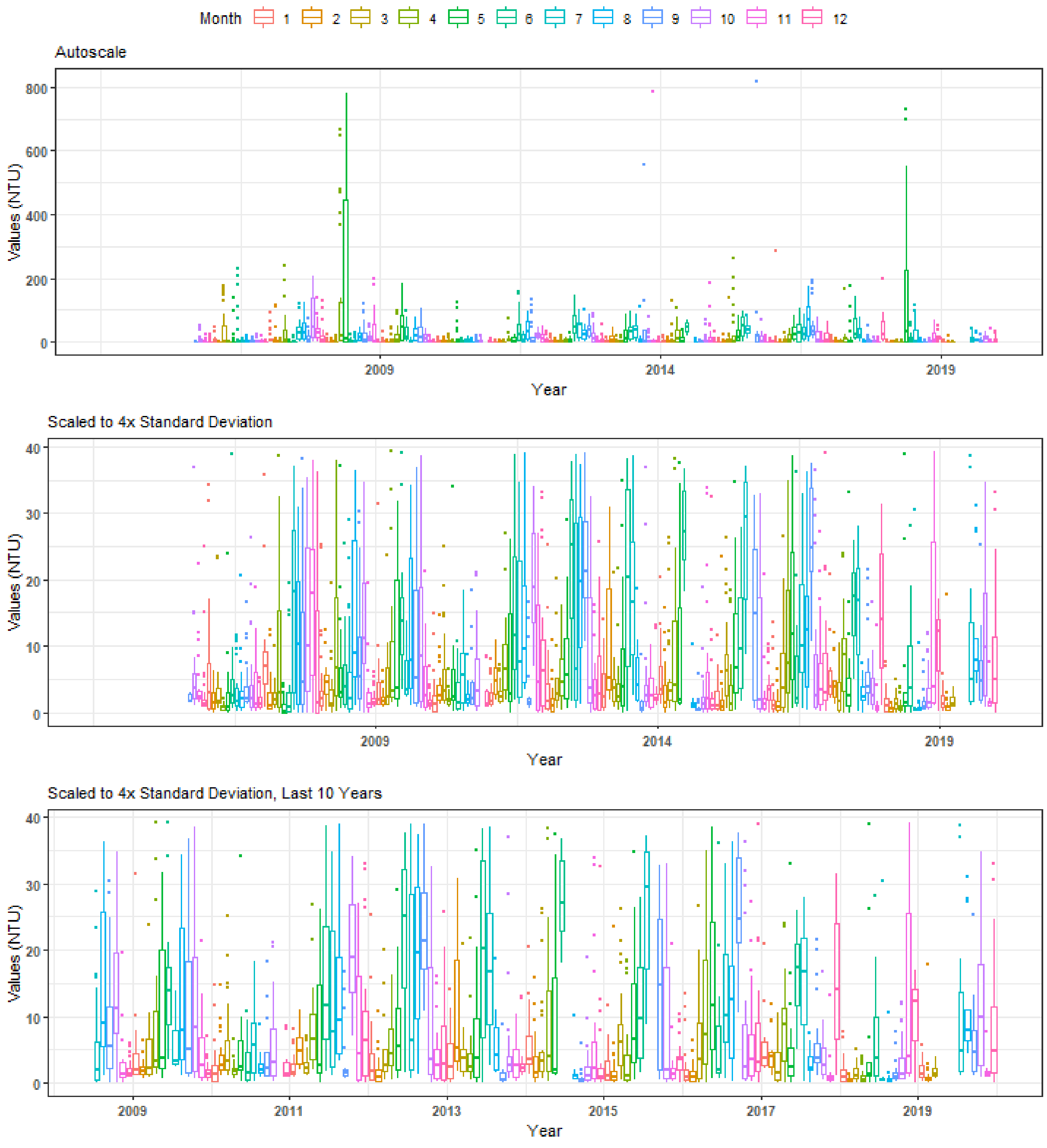


Scaled to 4x Standard Deviation, Last 10 Years



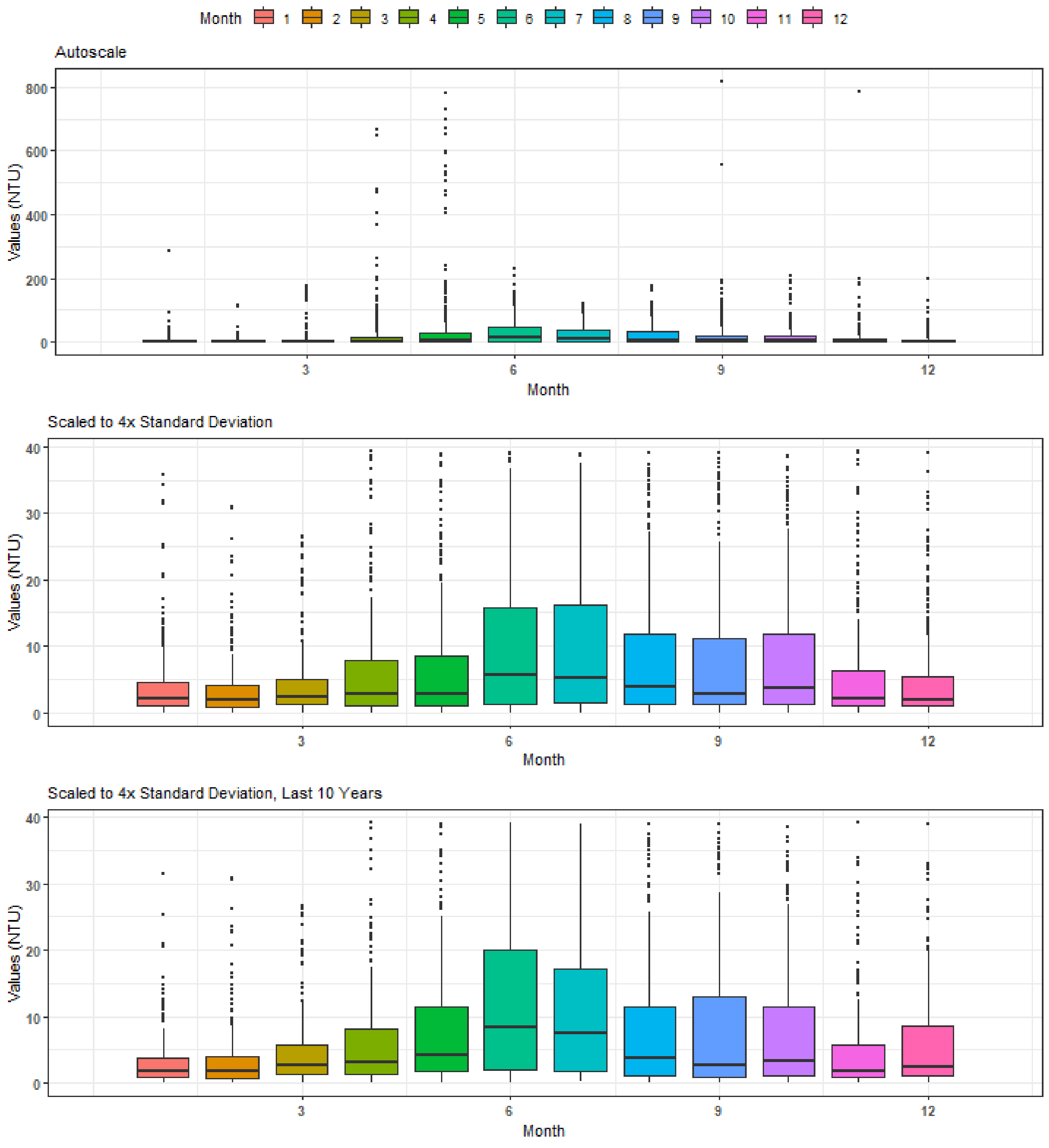
Summary Box Plots for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP1A

By Year & Month



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

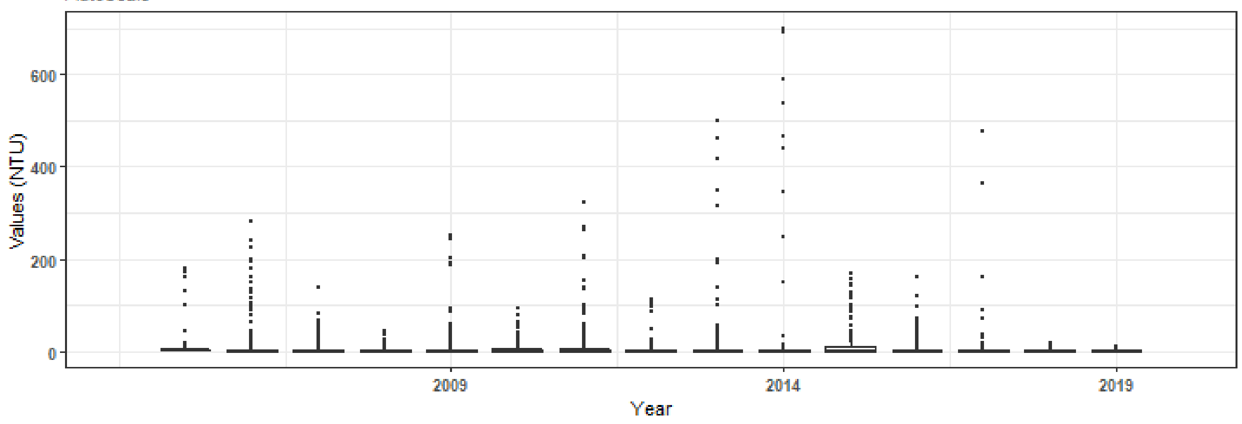
By Month



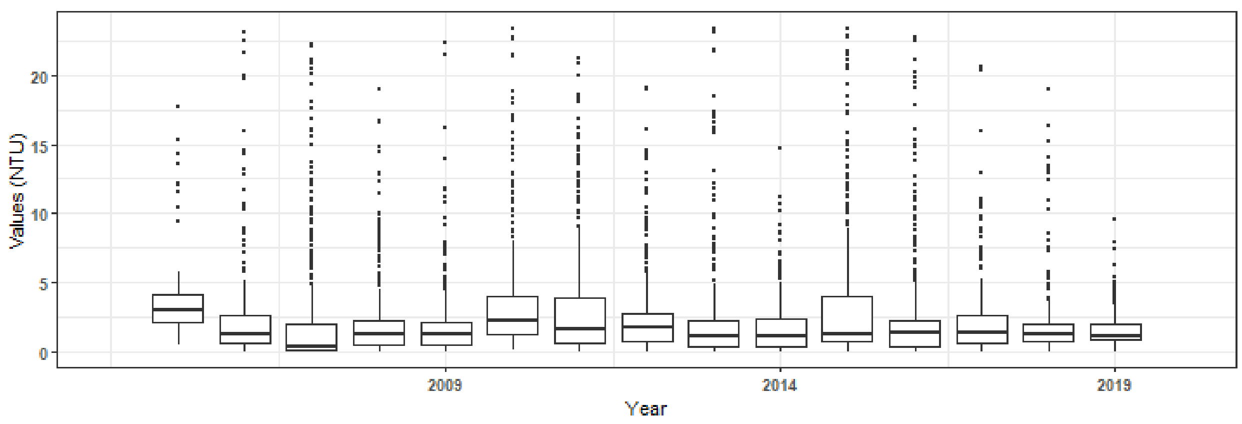
Summary Box Plots for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP2B

By Year

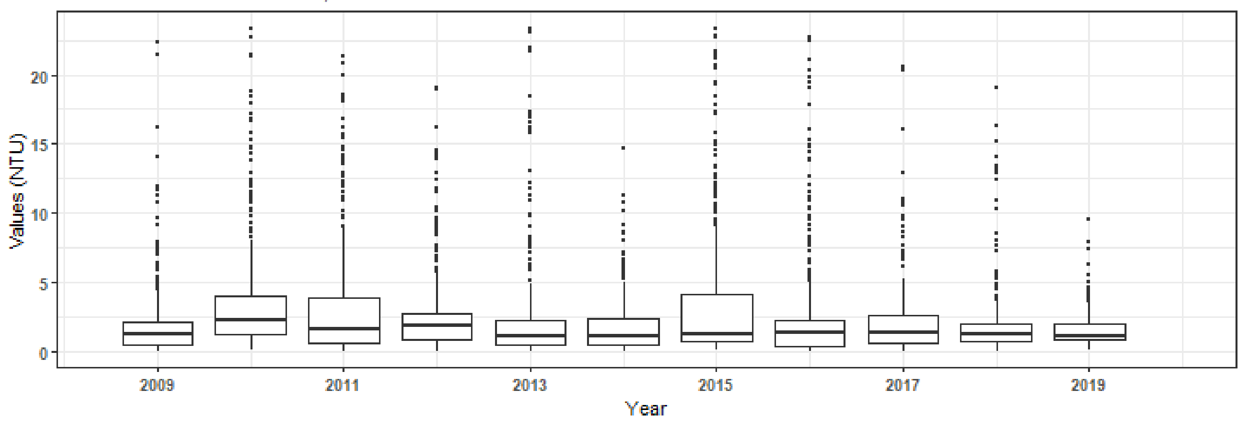
Autoscale



Scaled to 4x Standard Deviation

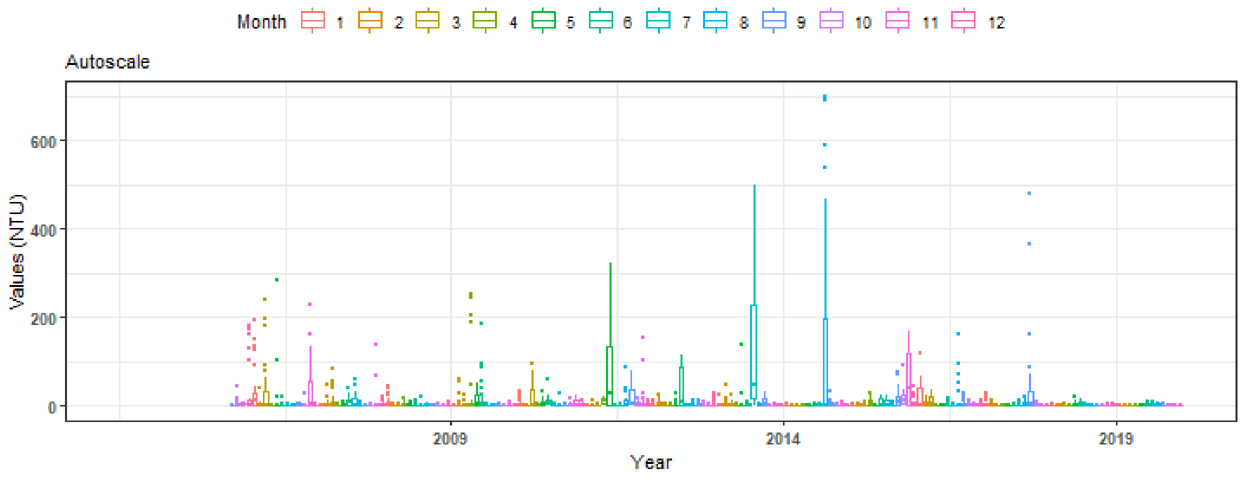


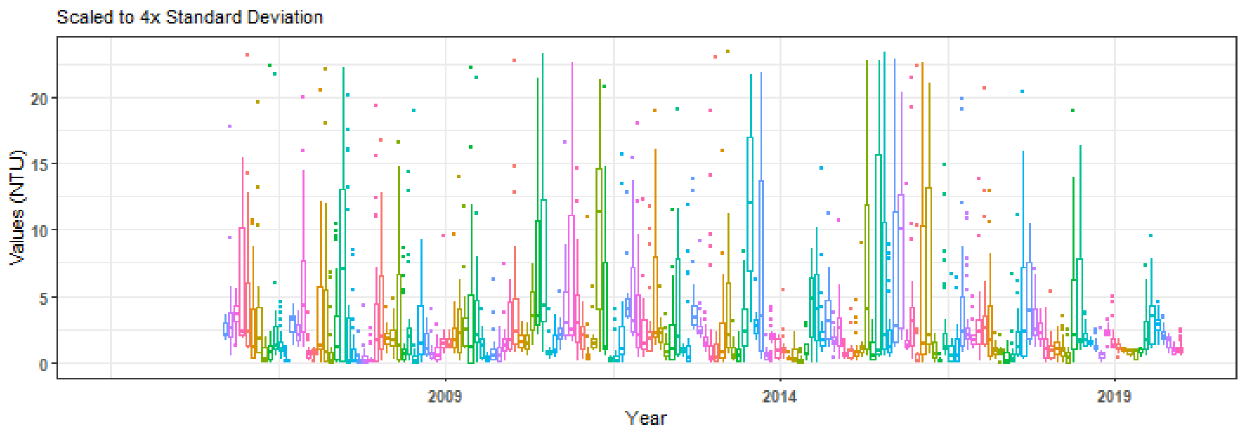
Scaled to 4x Standard Deviation, Last 10 Years

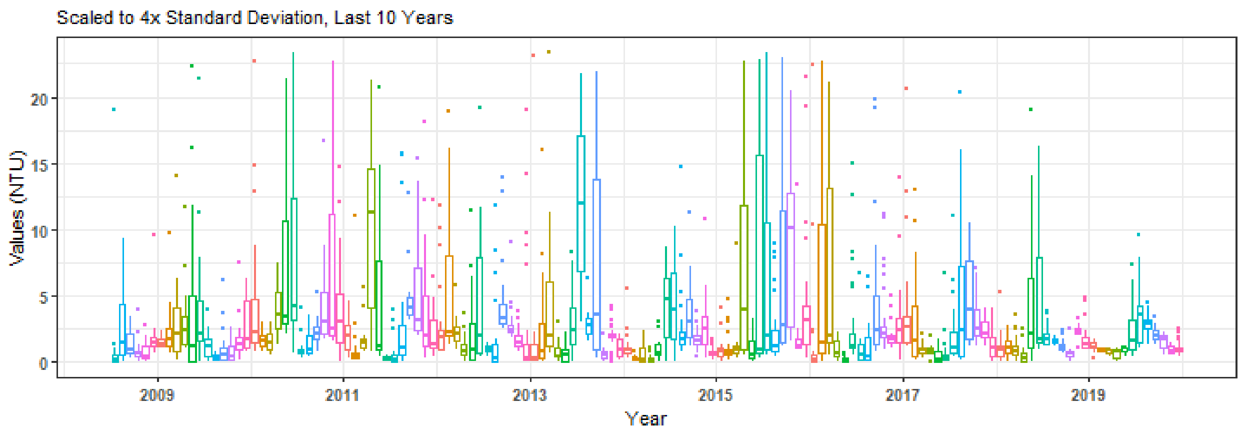


Summary Box Plots for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP2B

By Year & Month

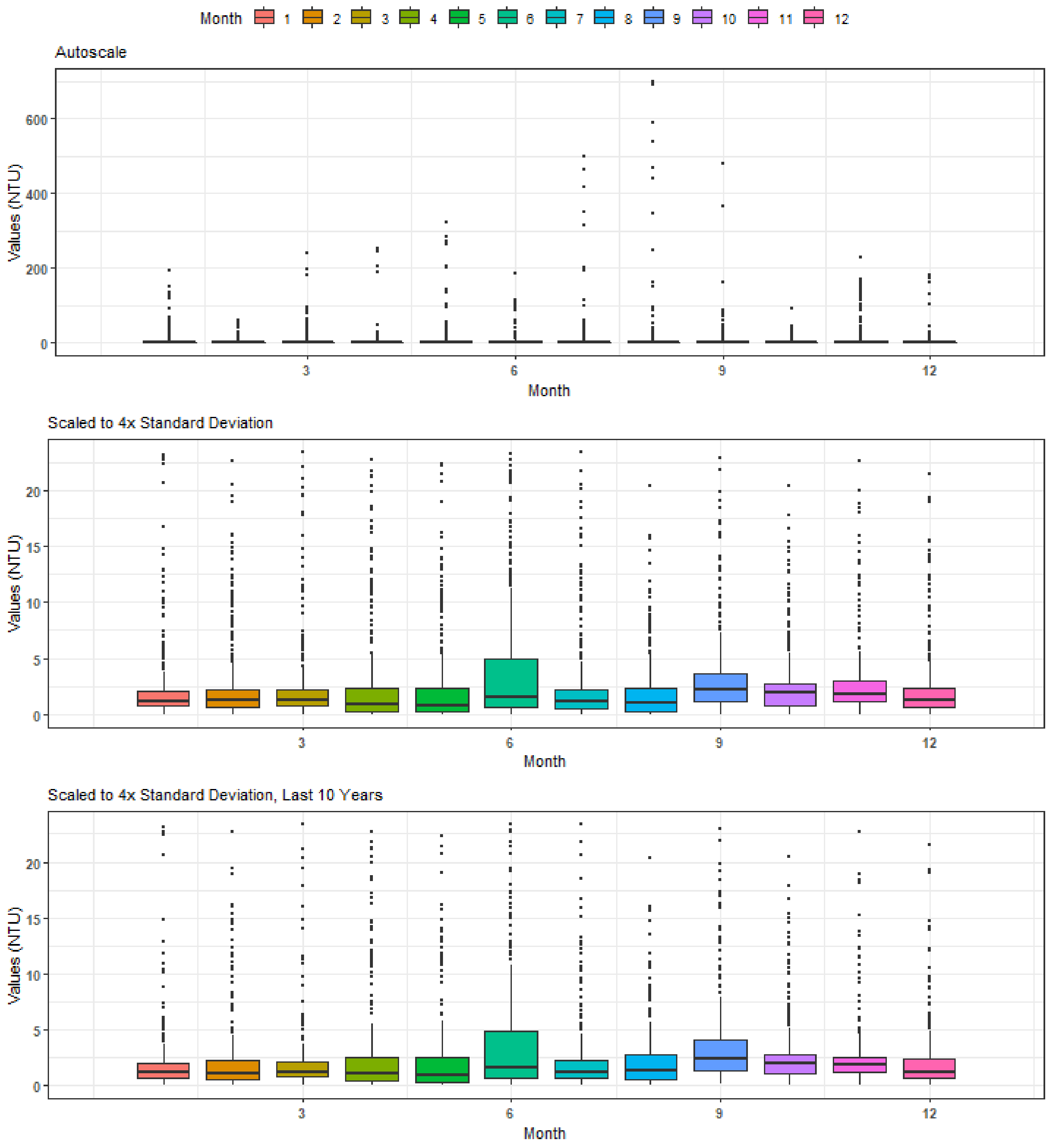






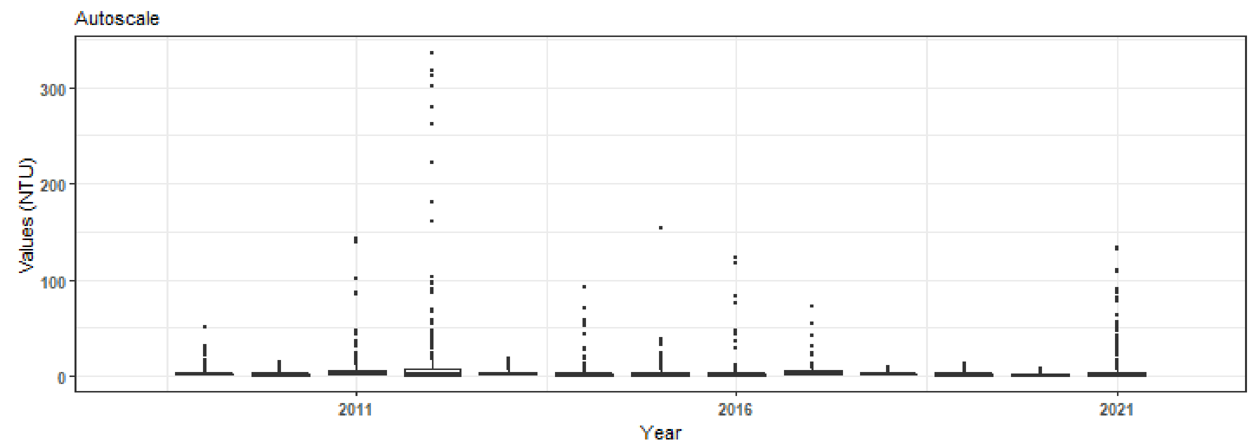
Summary Box Plots for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP2B

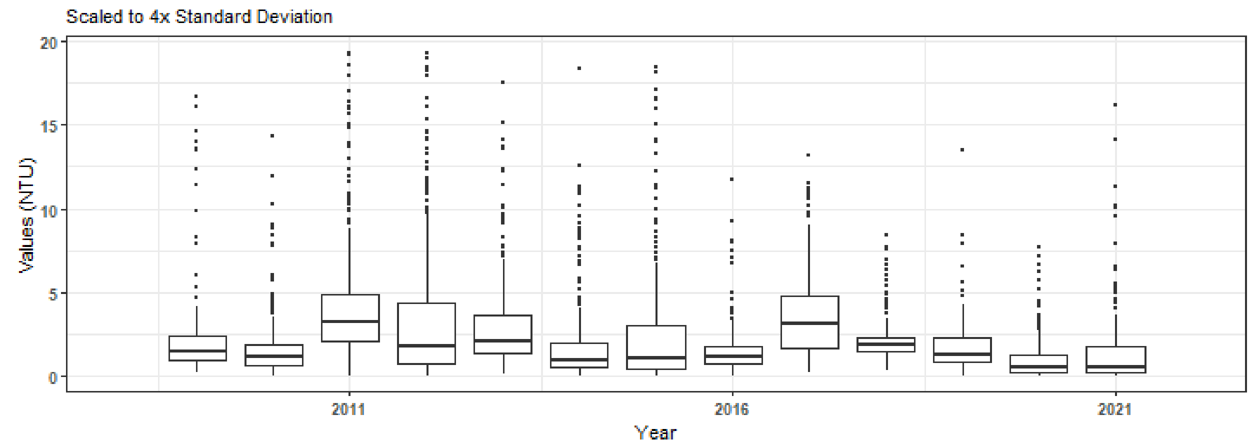
By Month

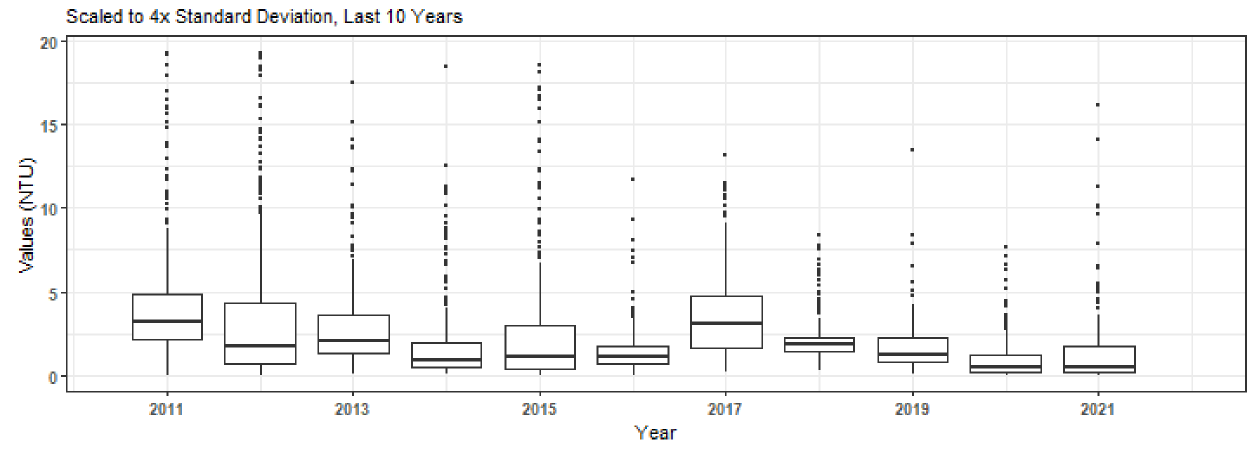


Summary Box Plots for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP3C

By Year

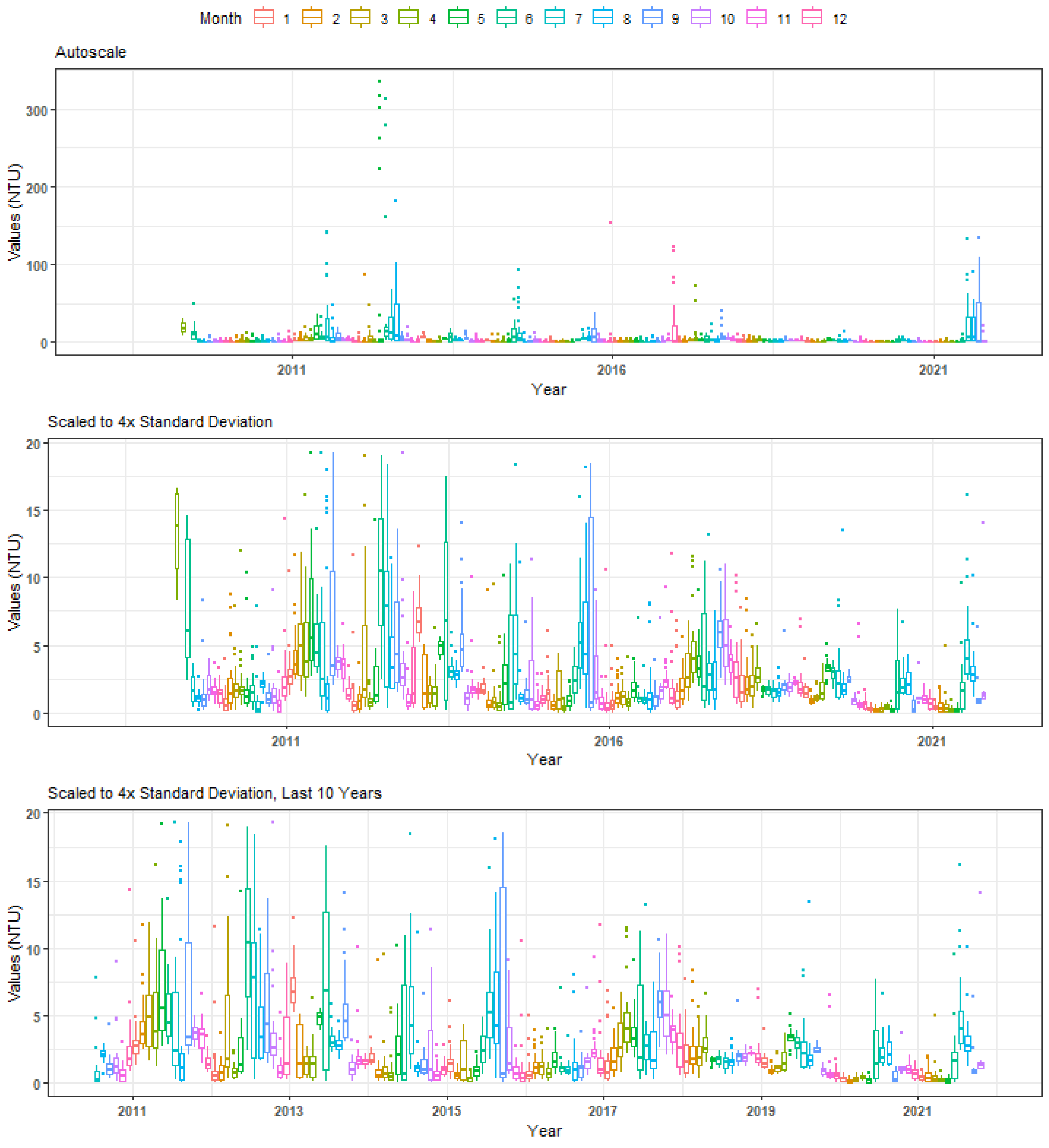






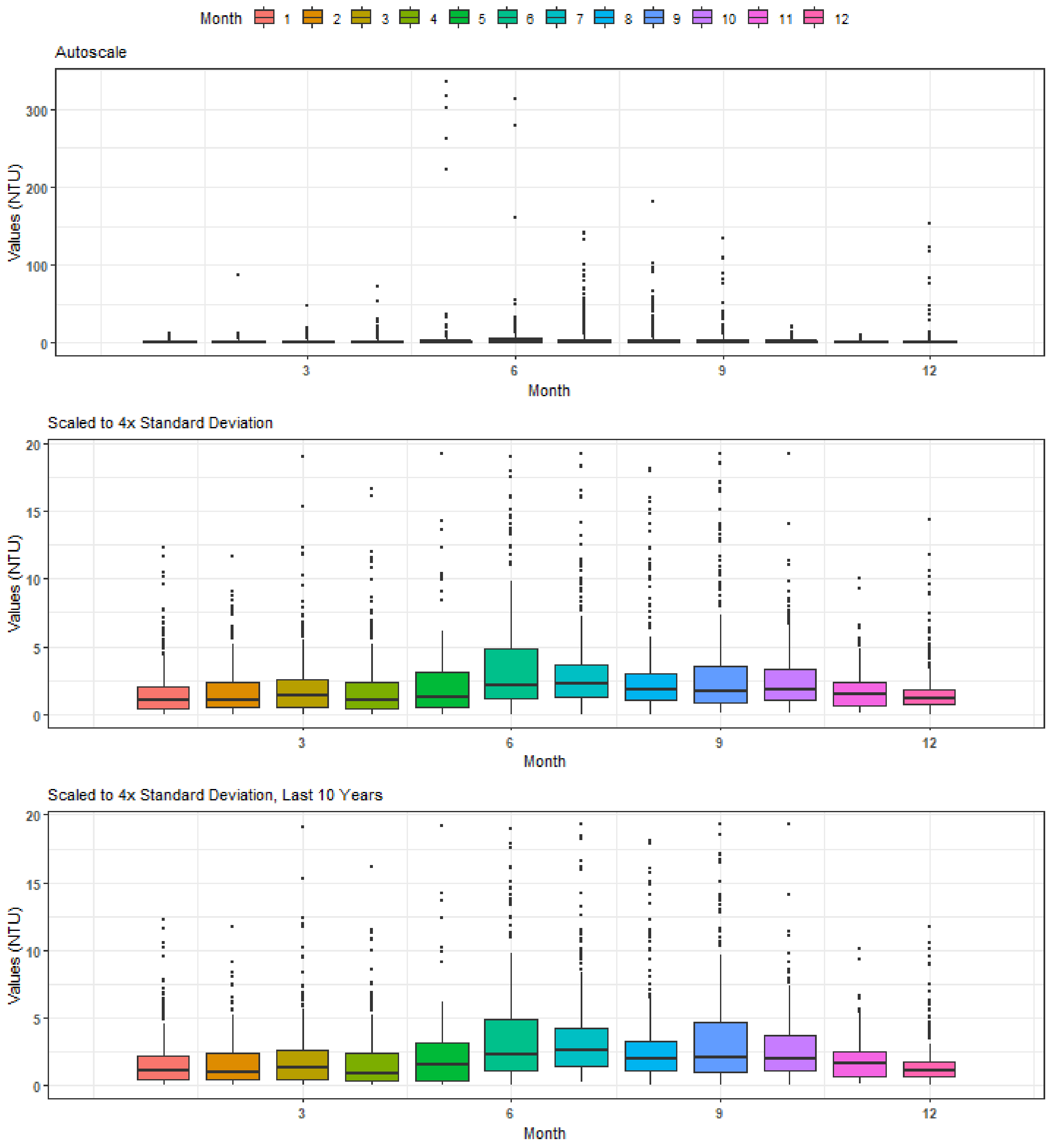
Summary Box Plots for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP3C

By Year & Month



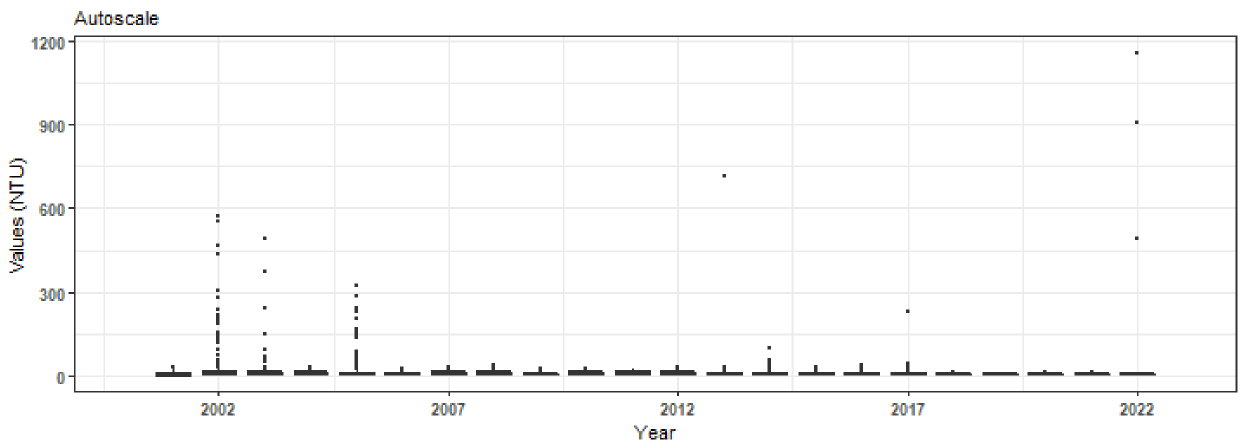
Summary Box Plots for Matlacha Pass Aquatic Preserve
512 | Matlacha Pass Aquatic Preserve Continuous Water Quality Monitoring Program | MP3C

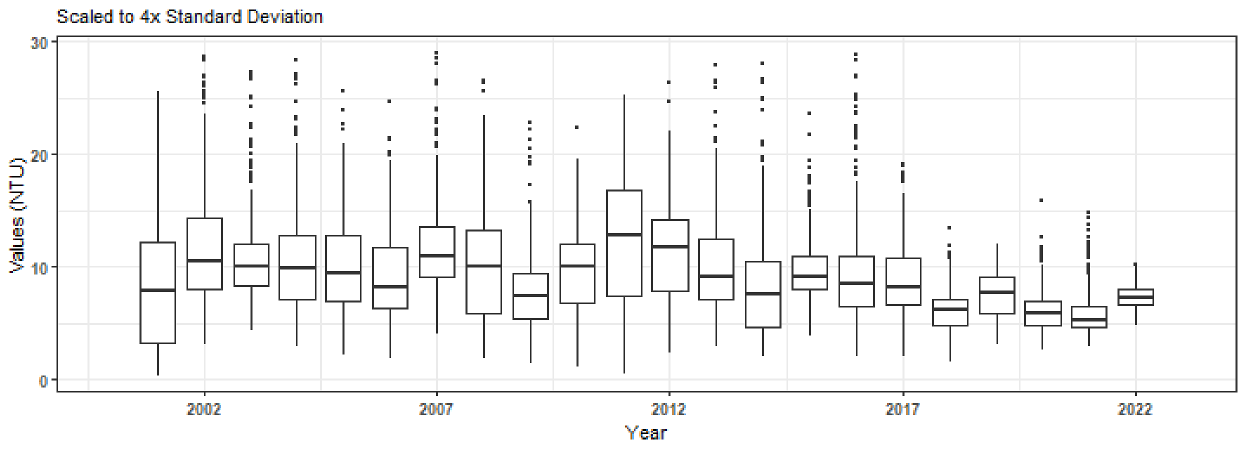
By Month

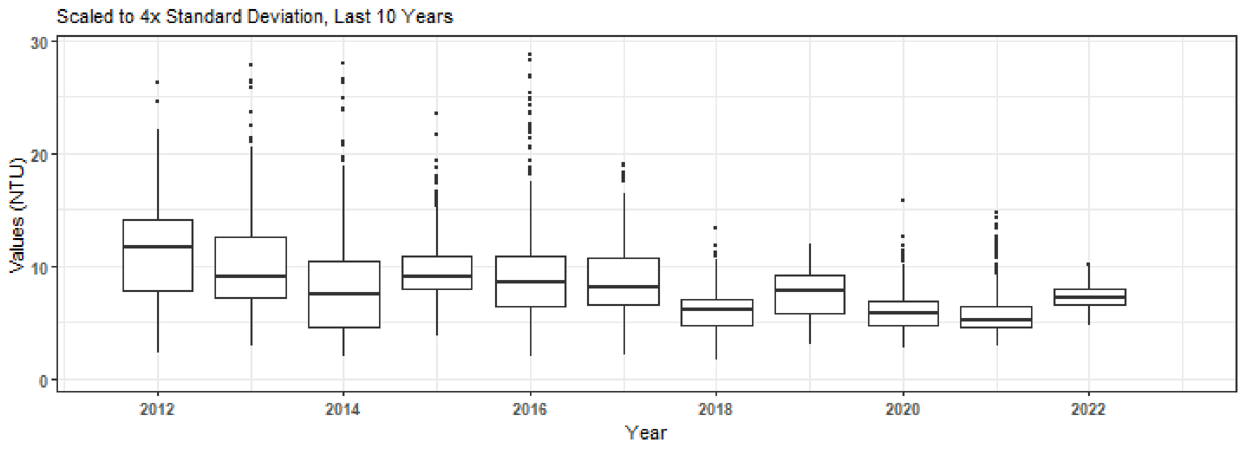


Summary Box Plots for Rookery Bay Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkblhwq

By Year

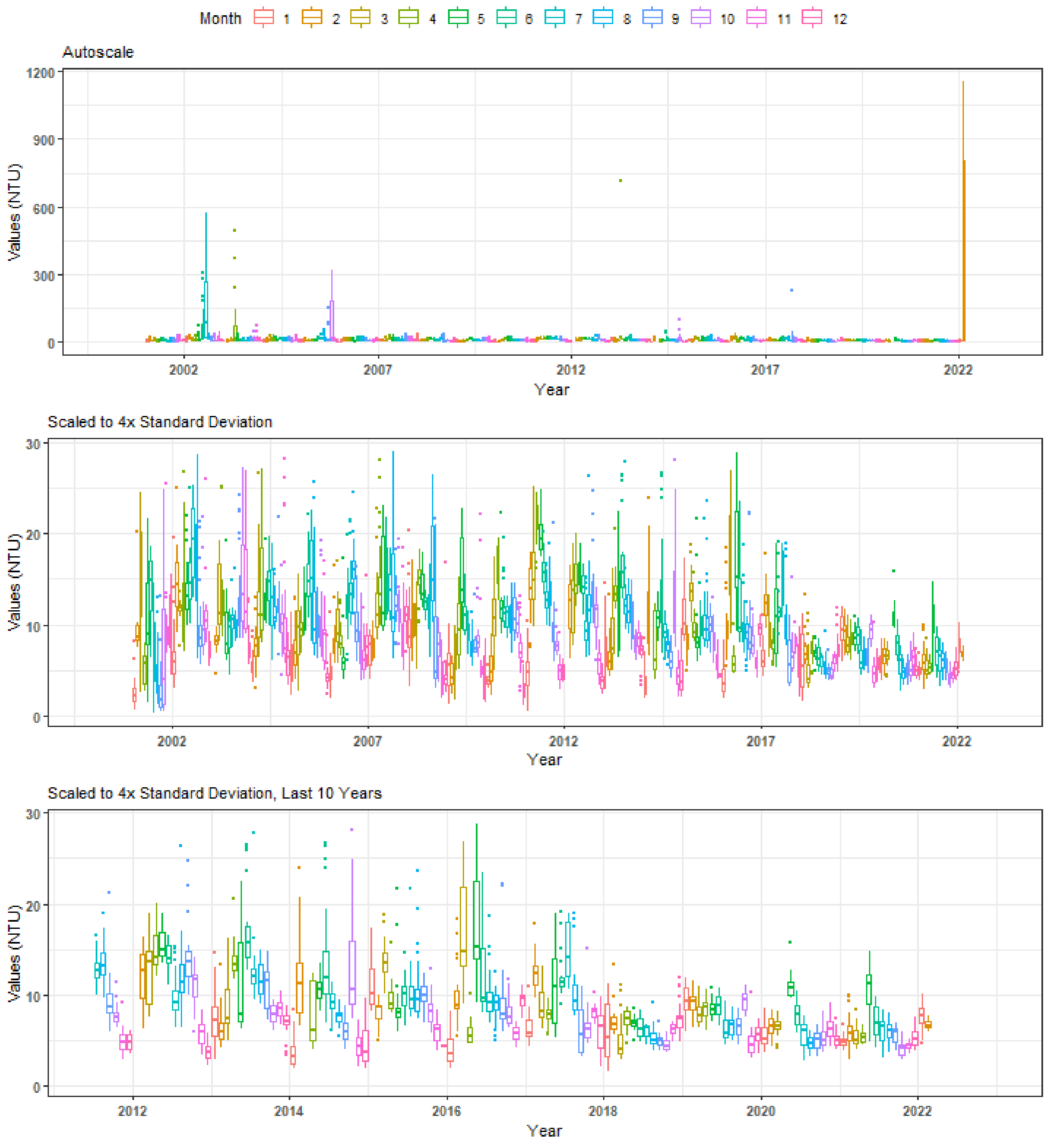






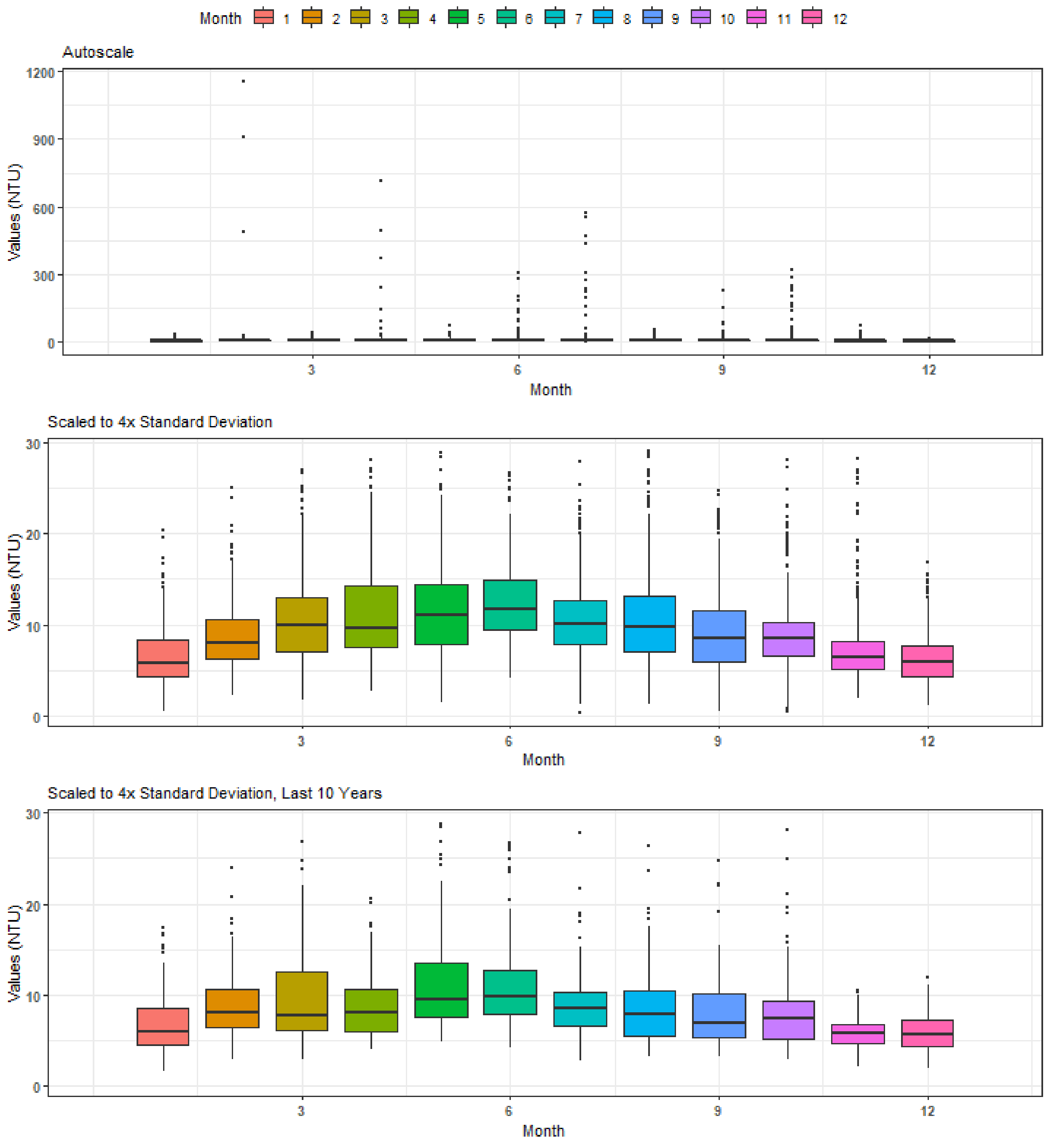
Summary Box Plots for Rookery Bay Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkblhwq

By Year & Month



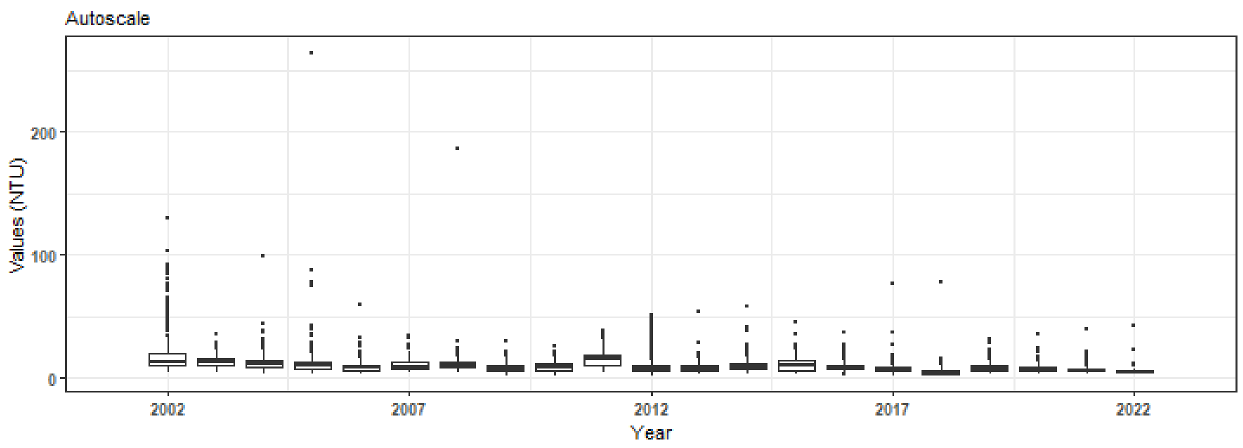
Summary Box Plots for Rookery Bay Aquatic Preserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkblhwq

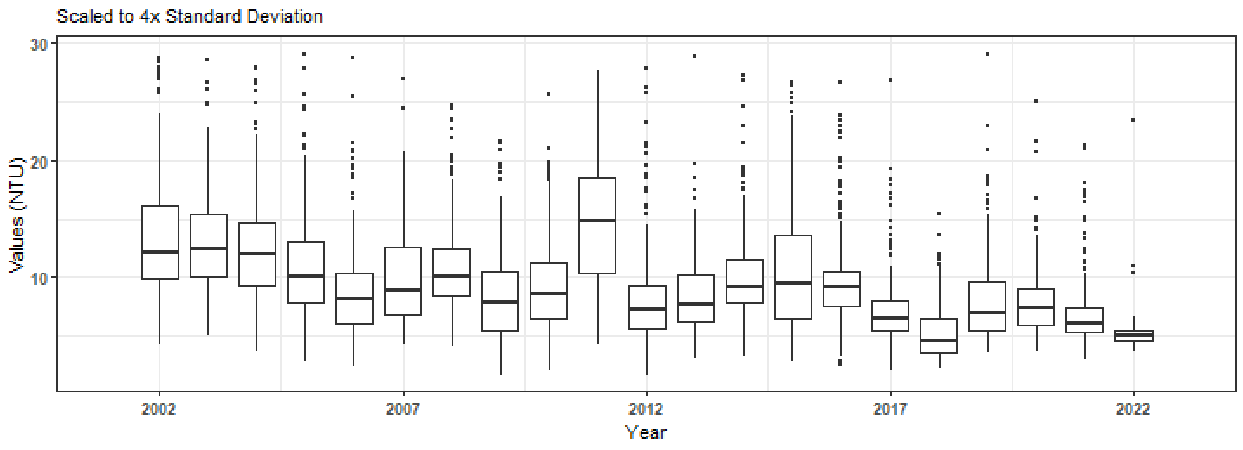
By Month

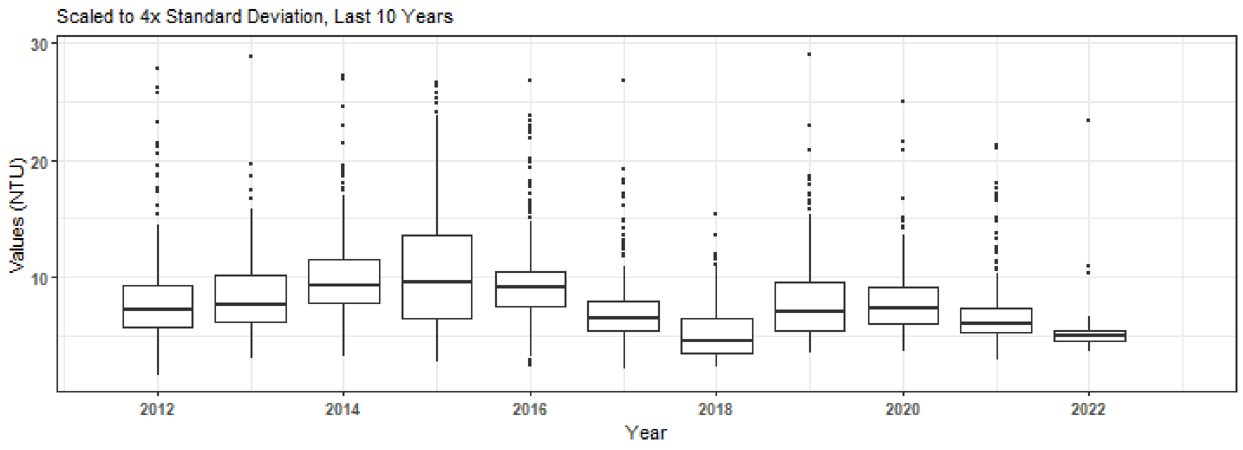


Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfbwq

By Year

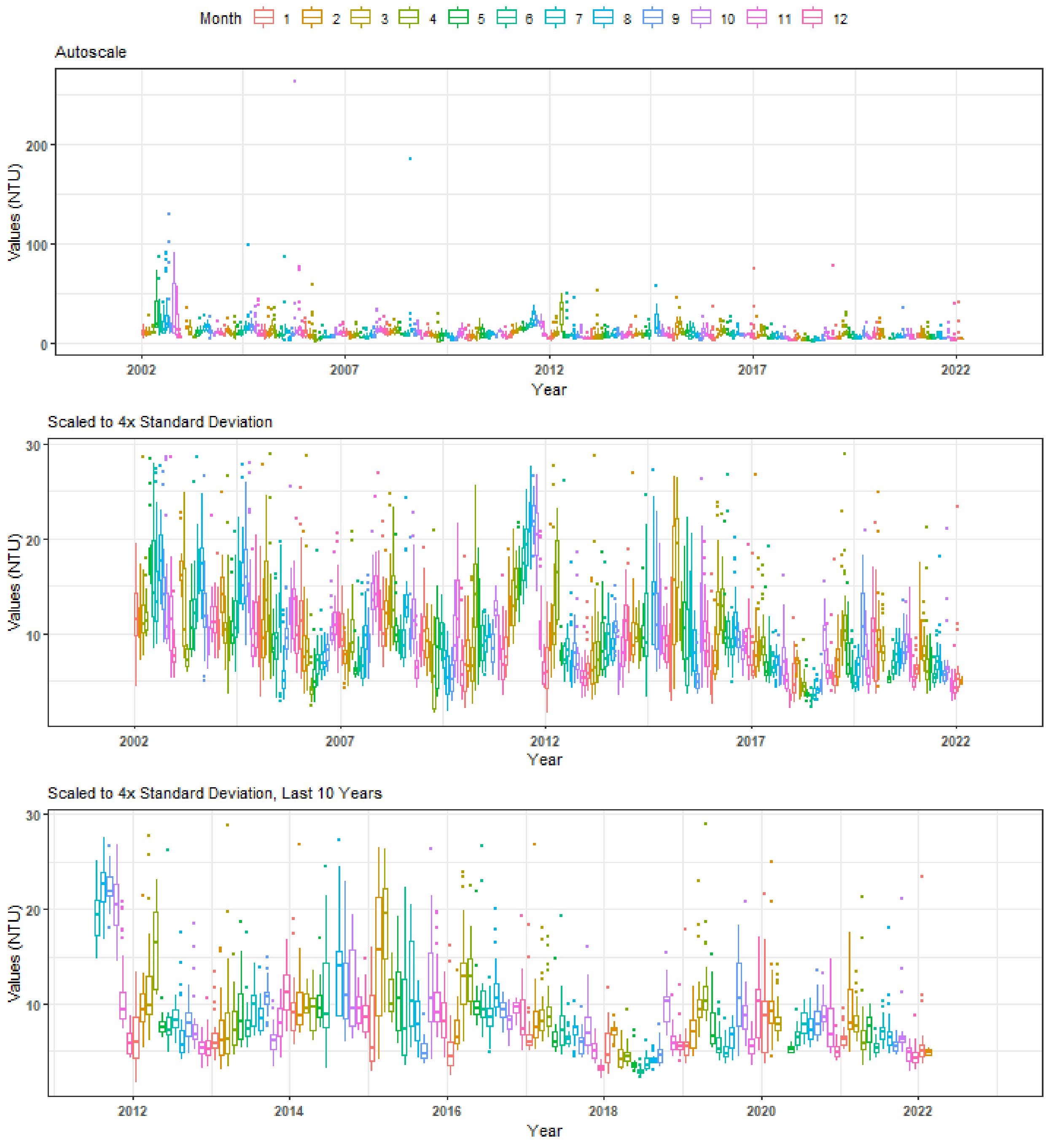






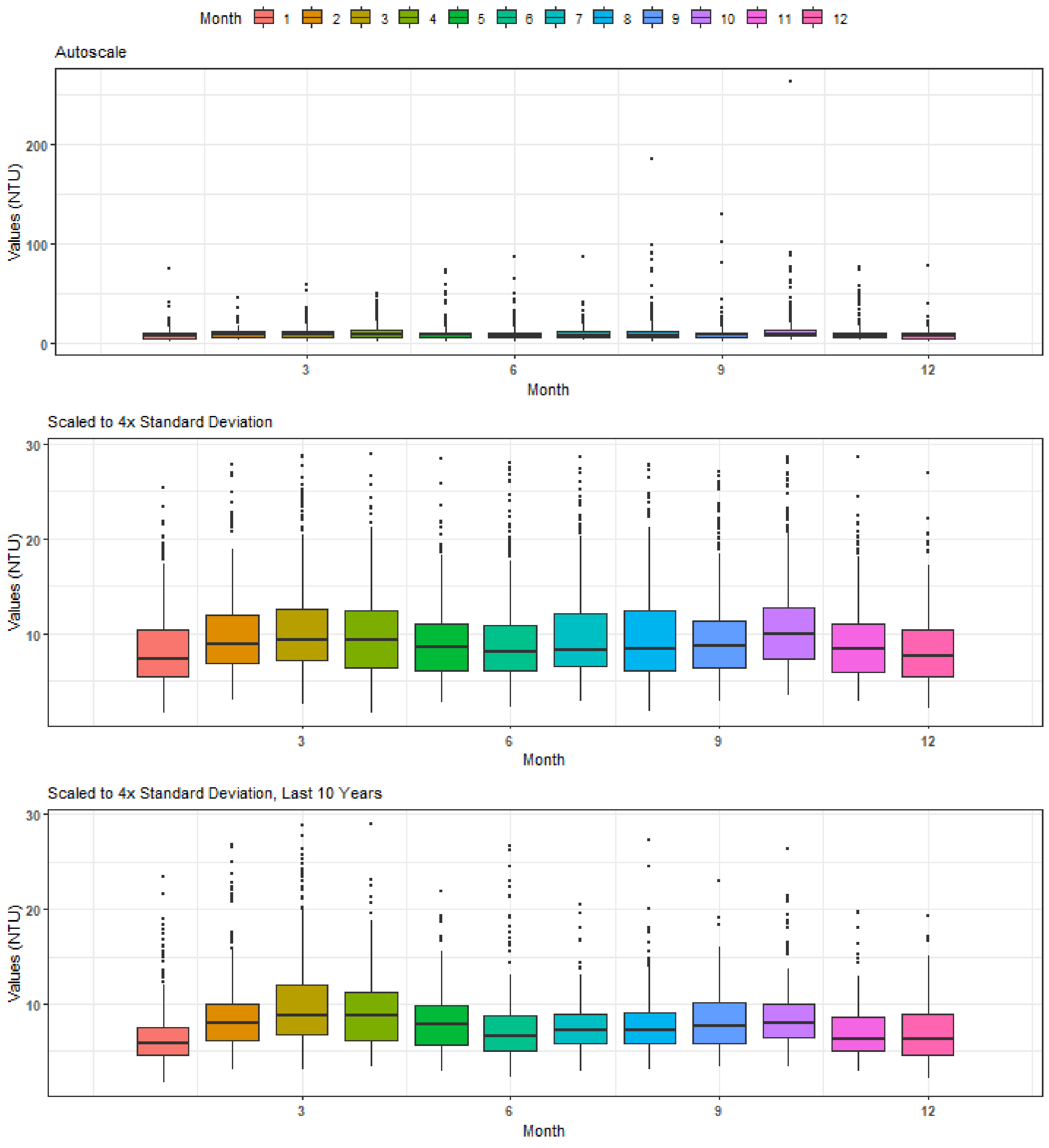
Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfbwq

By Year & Month



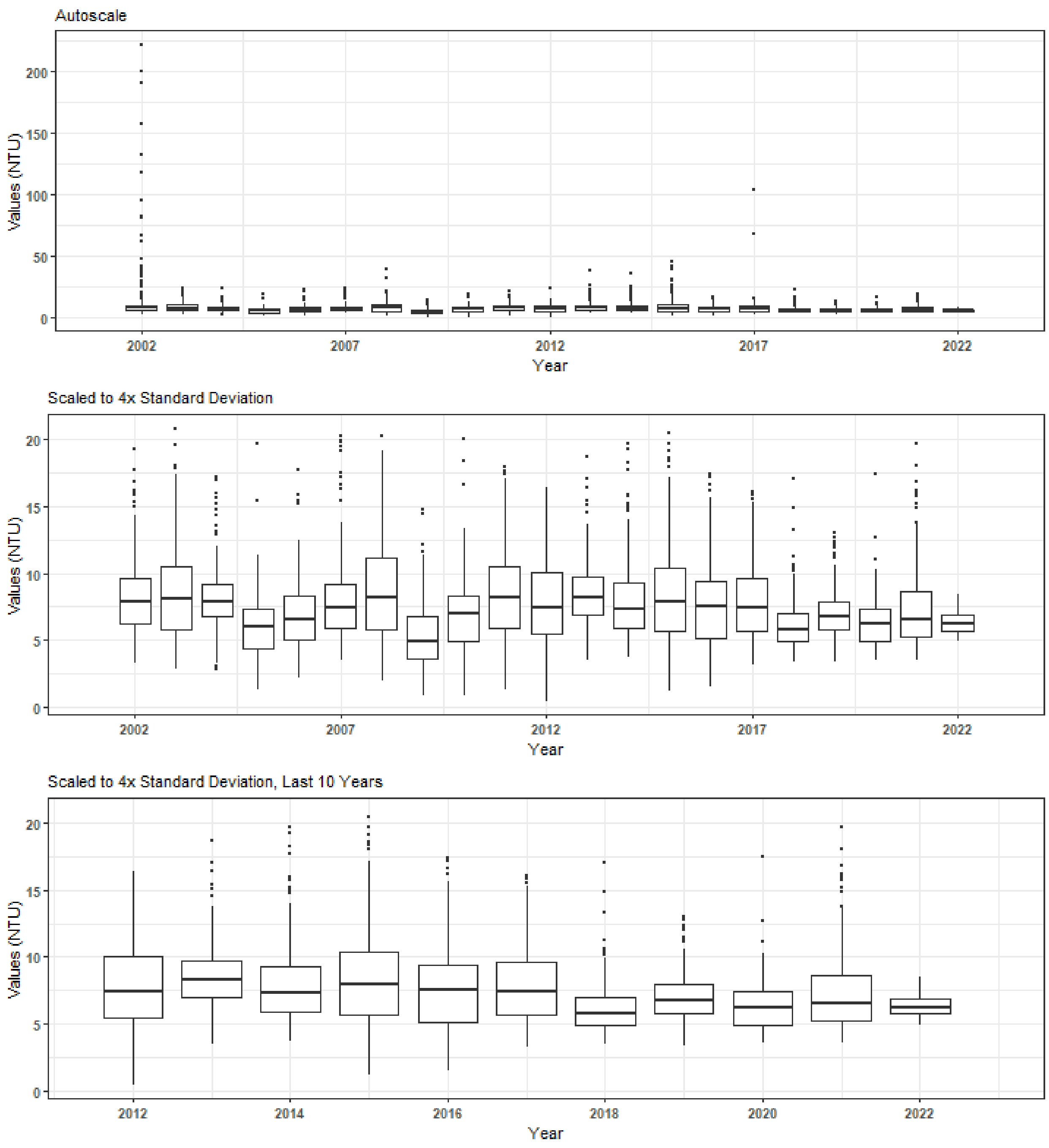
Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfbwq

By Month



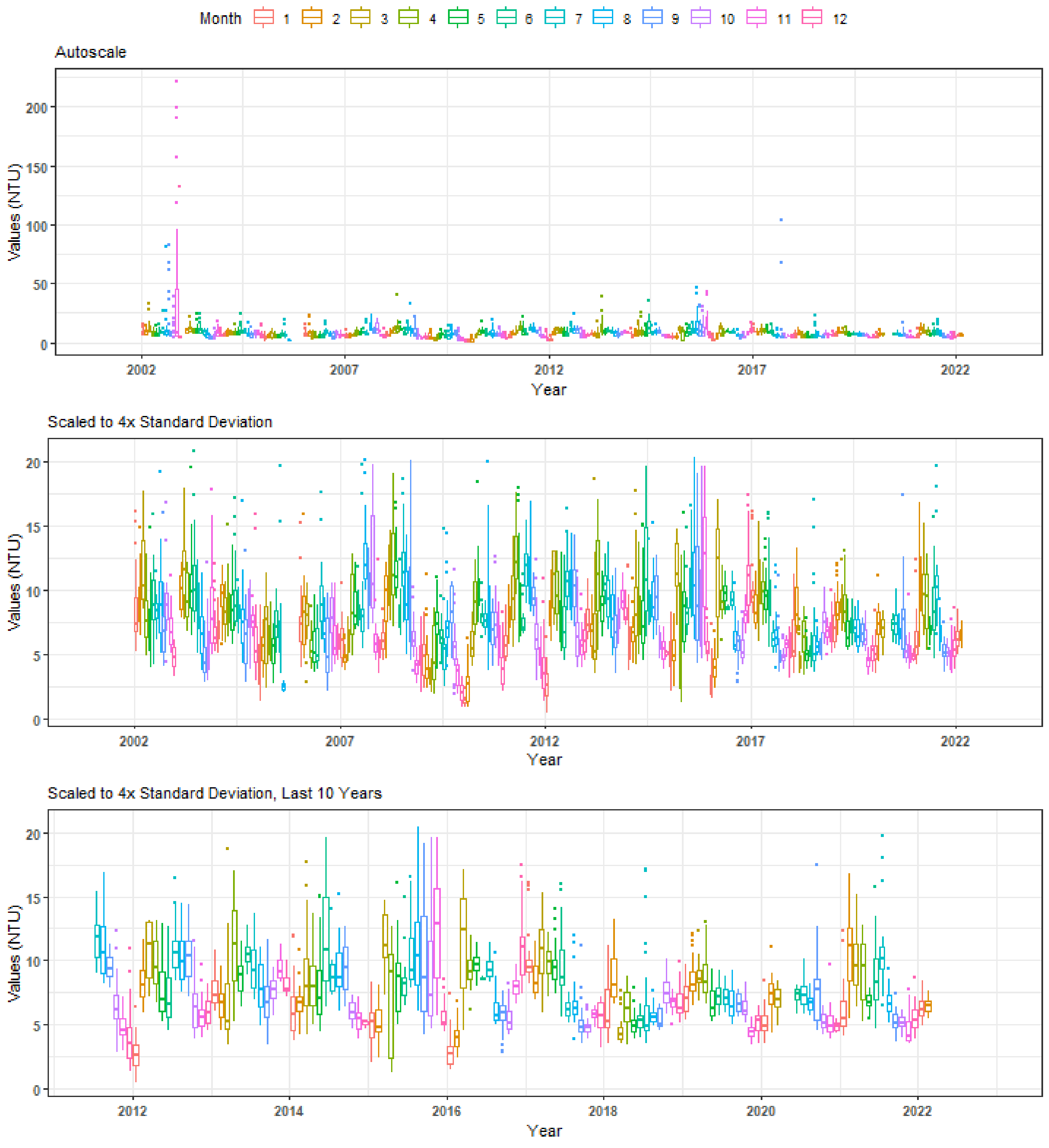
Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfuwq

By Year



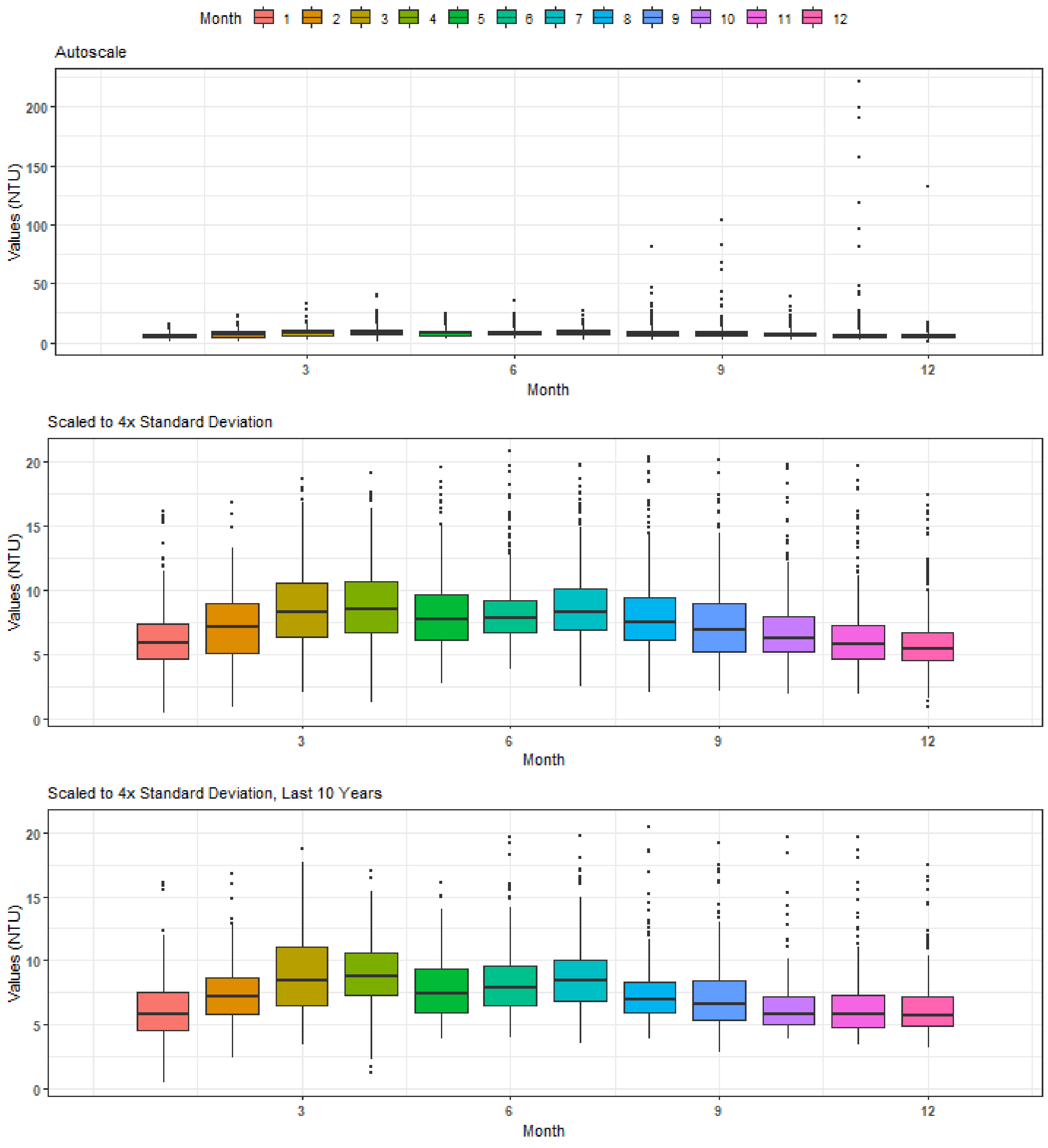
Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfuwq

By Year & Month



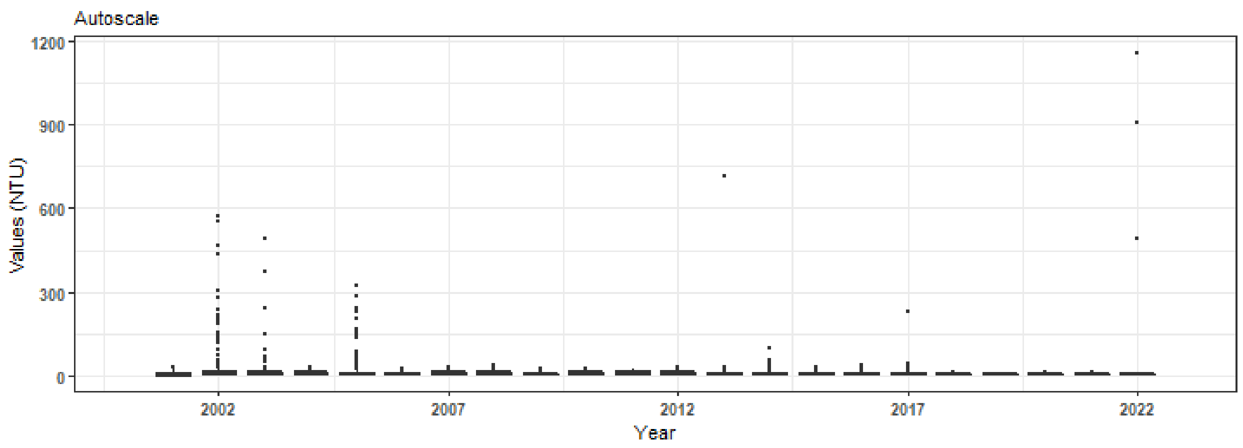
Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbfuwq

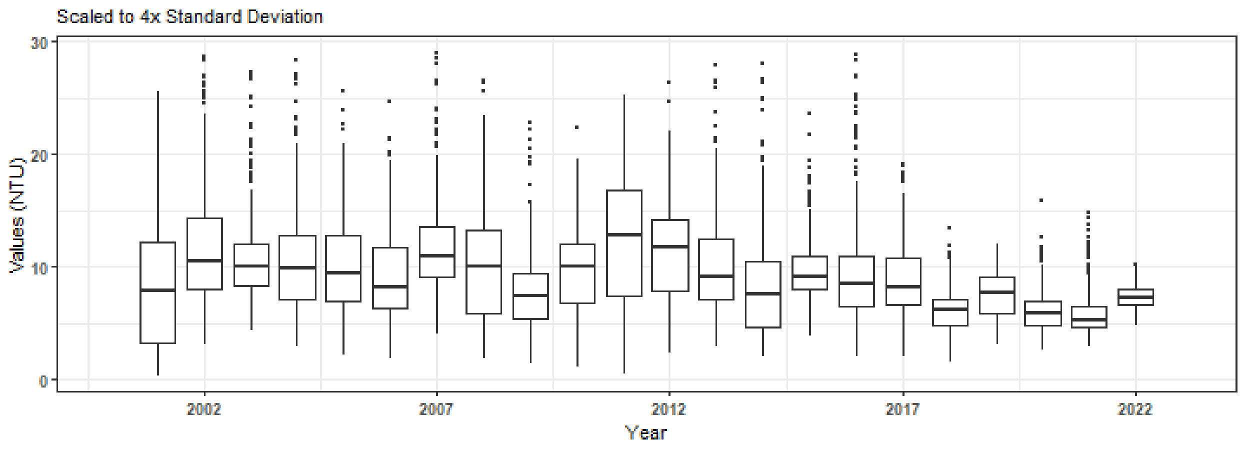
By Month

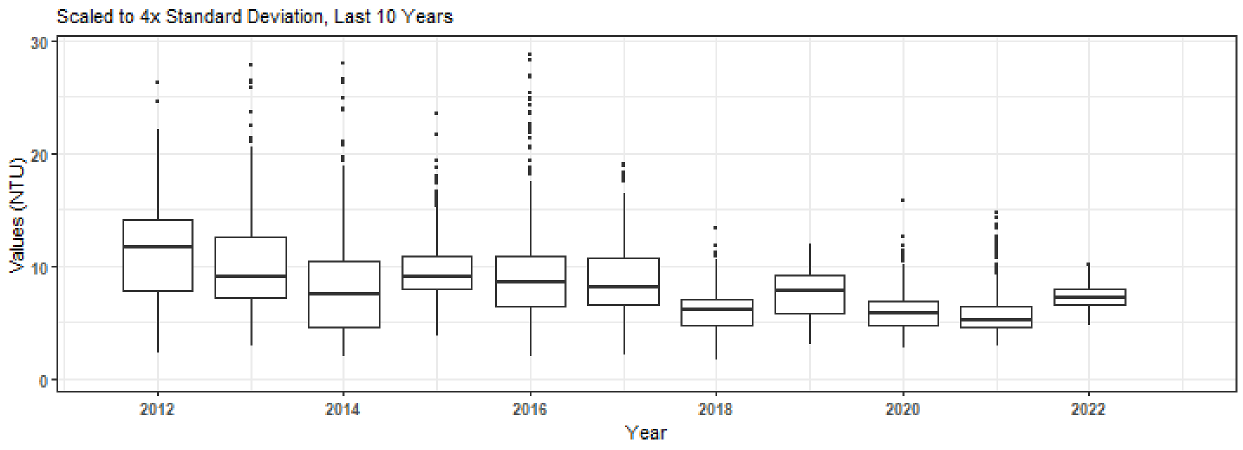


Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkblhwq

By Year

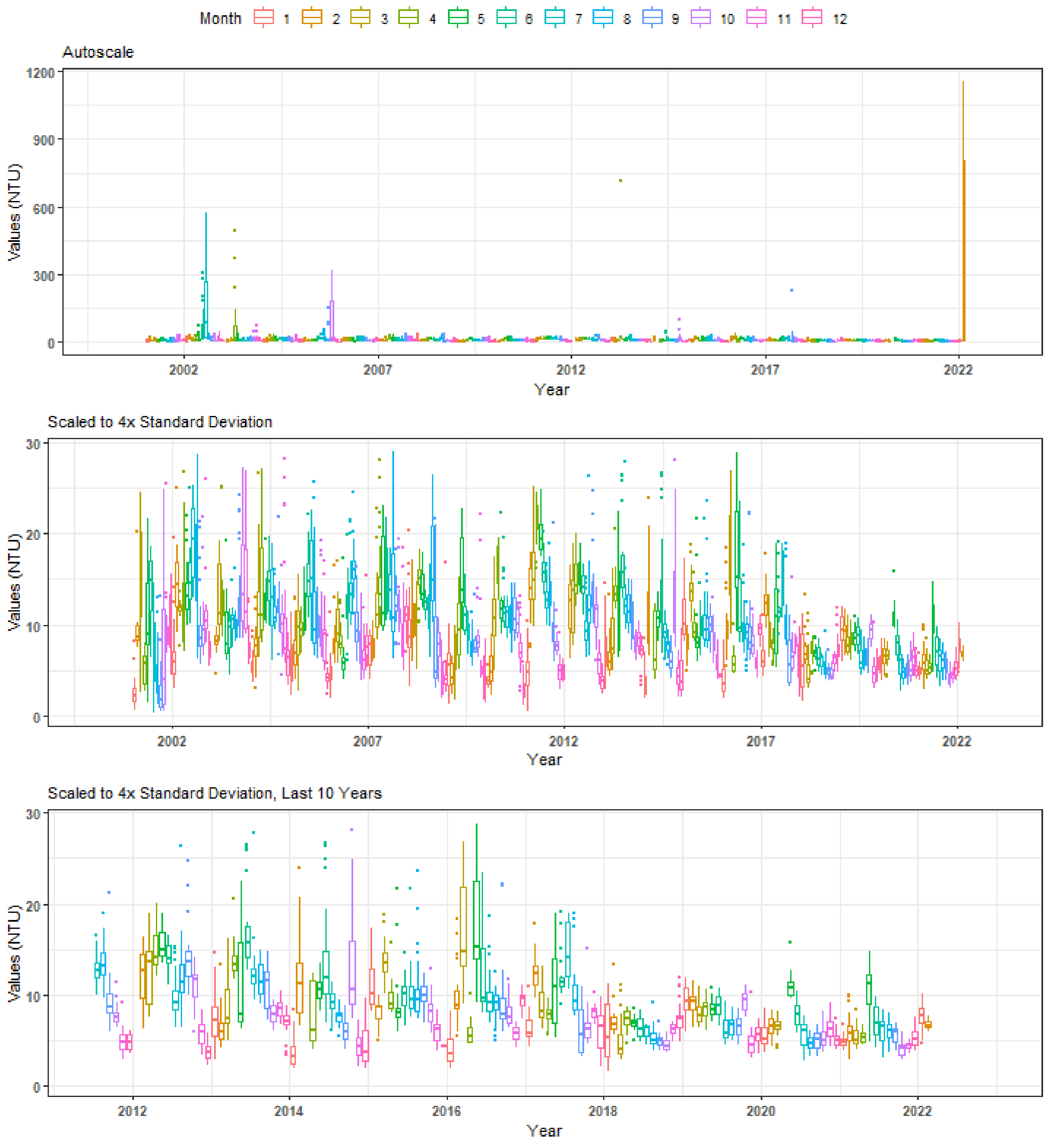






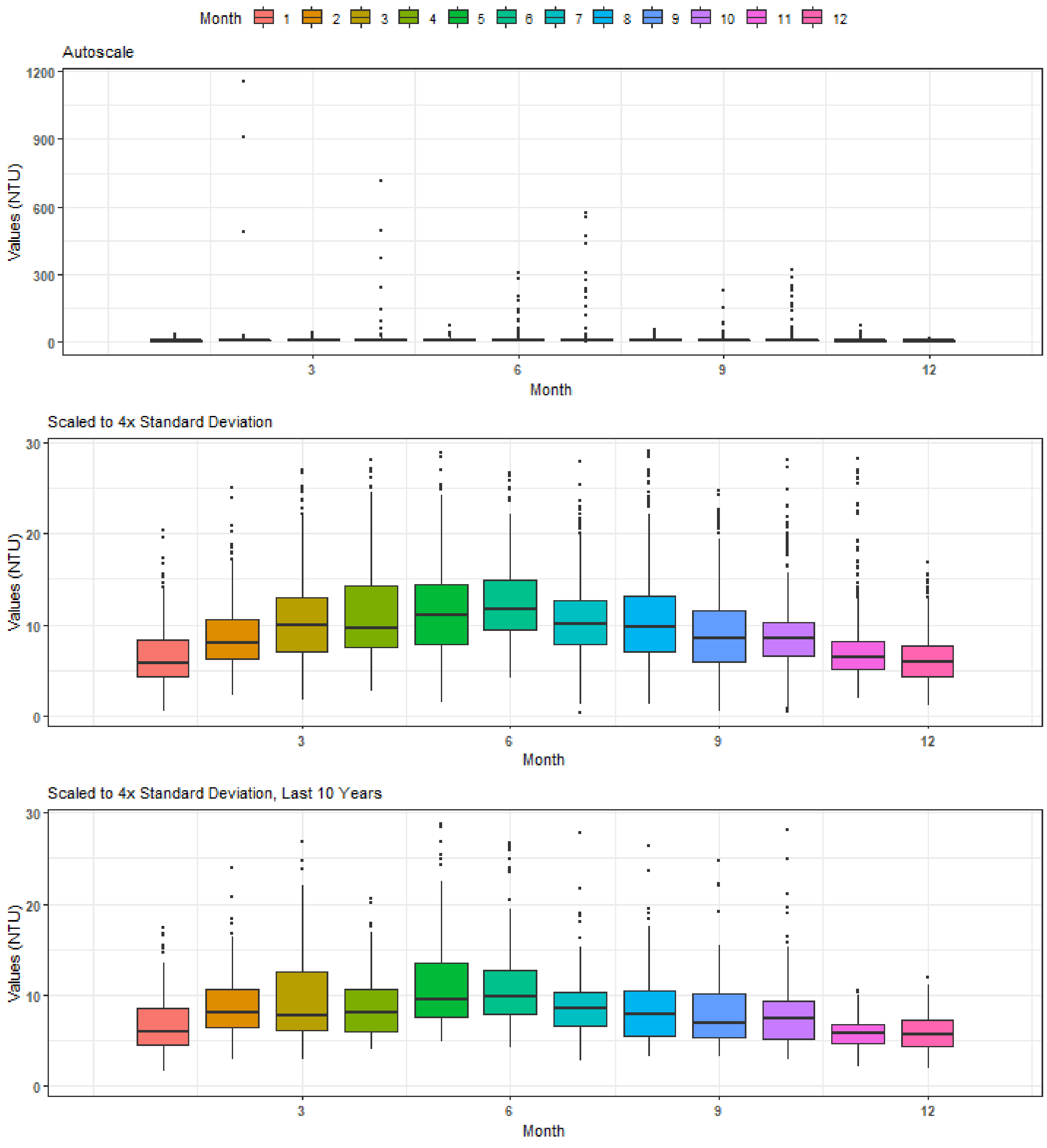
Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkblhwq

By Year & Month



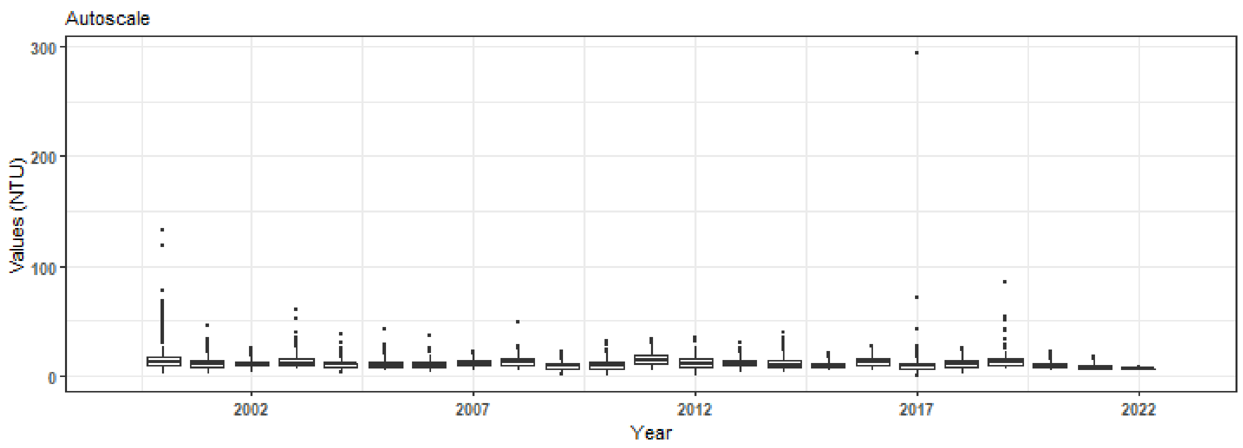
Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkblhwq

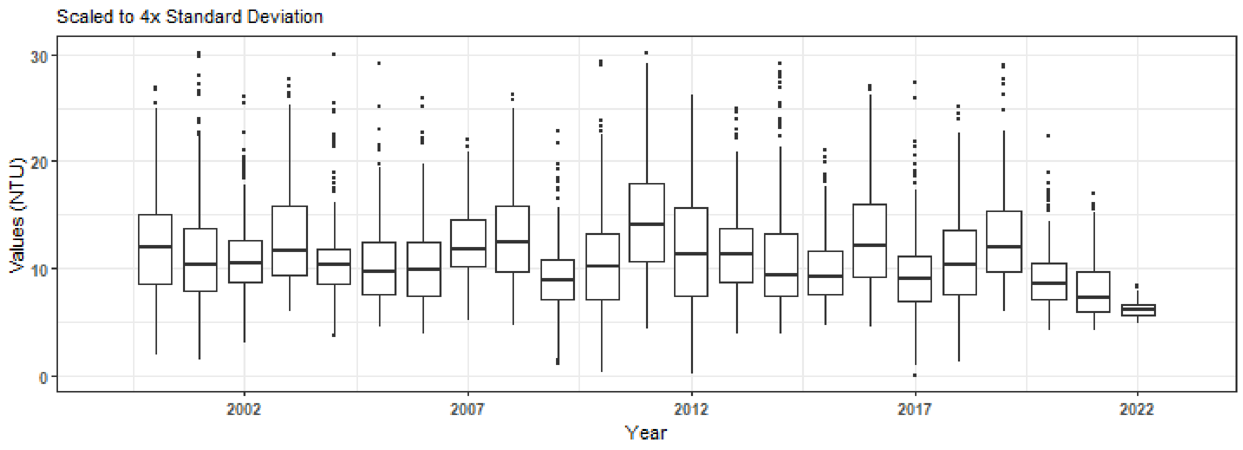
By Month

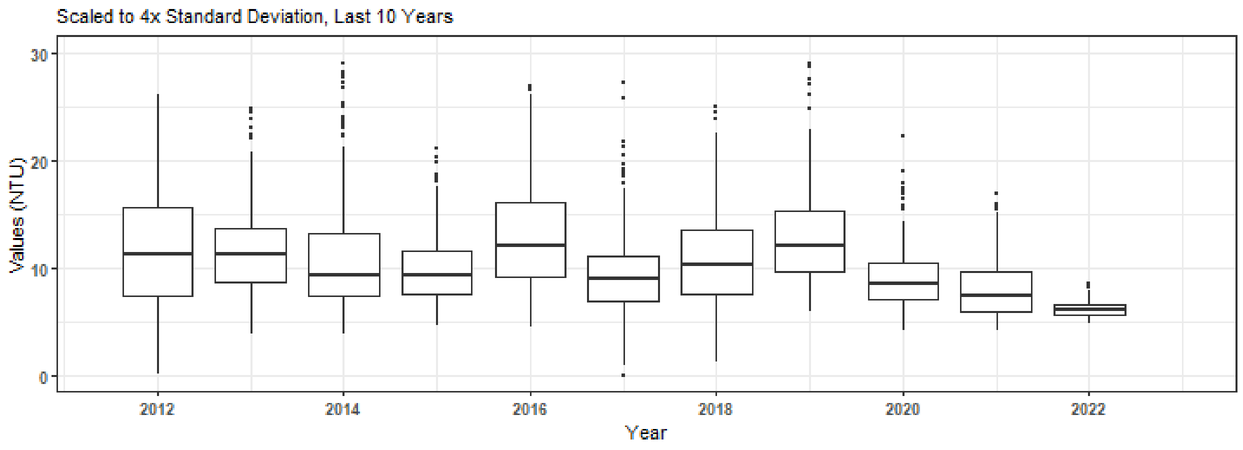


Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbmbwq

By Year

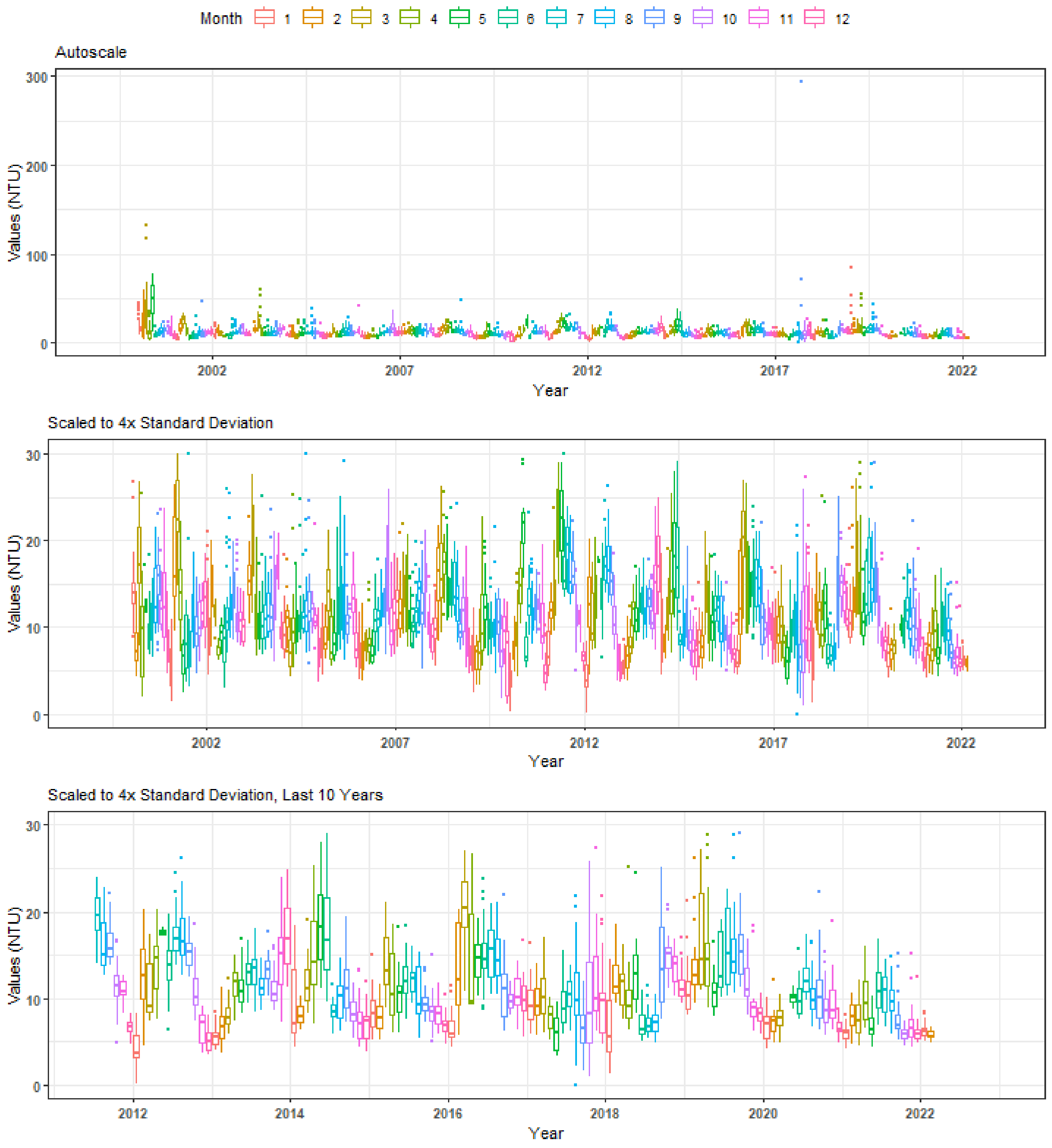






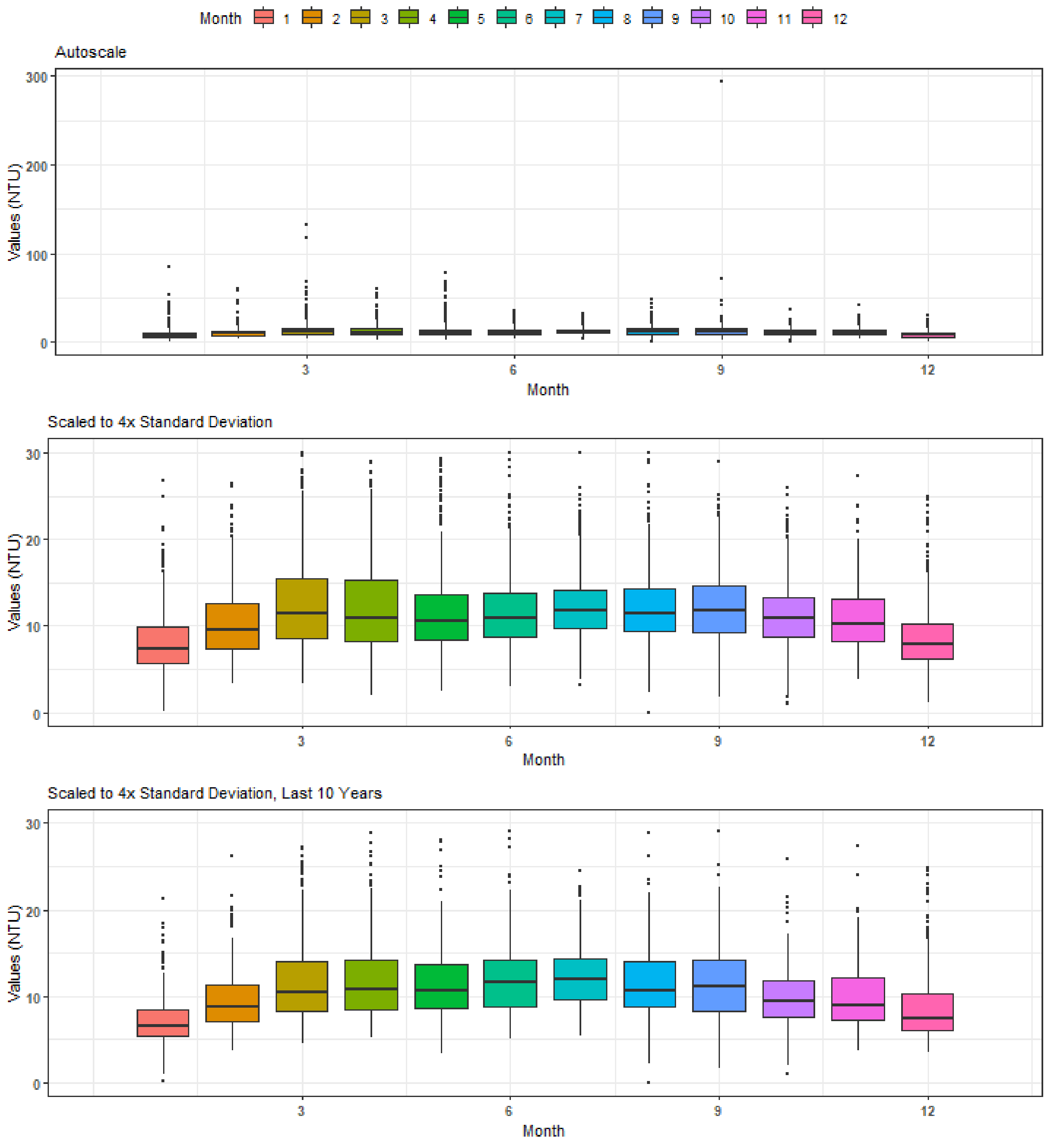
Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbmbwq

By Year & Month



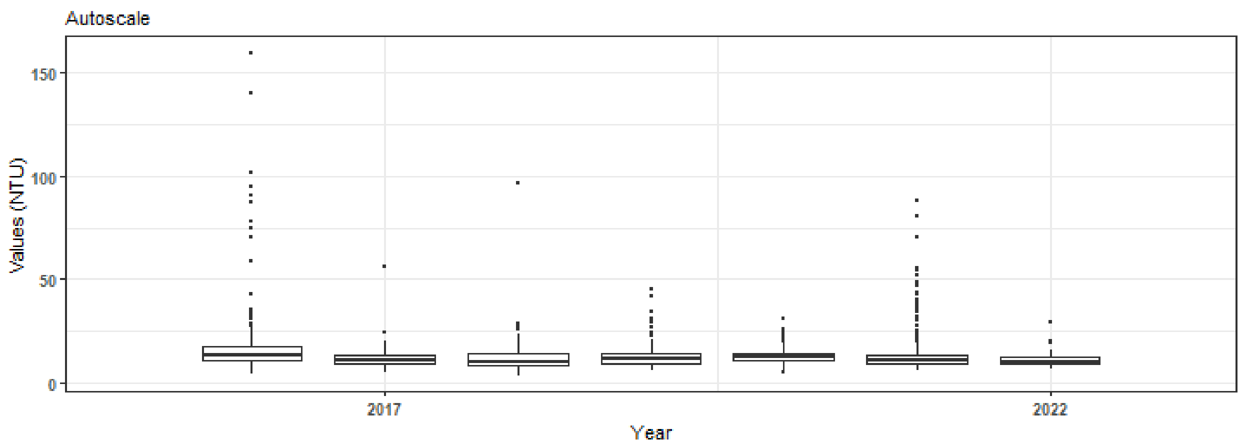
Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbmbwq

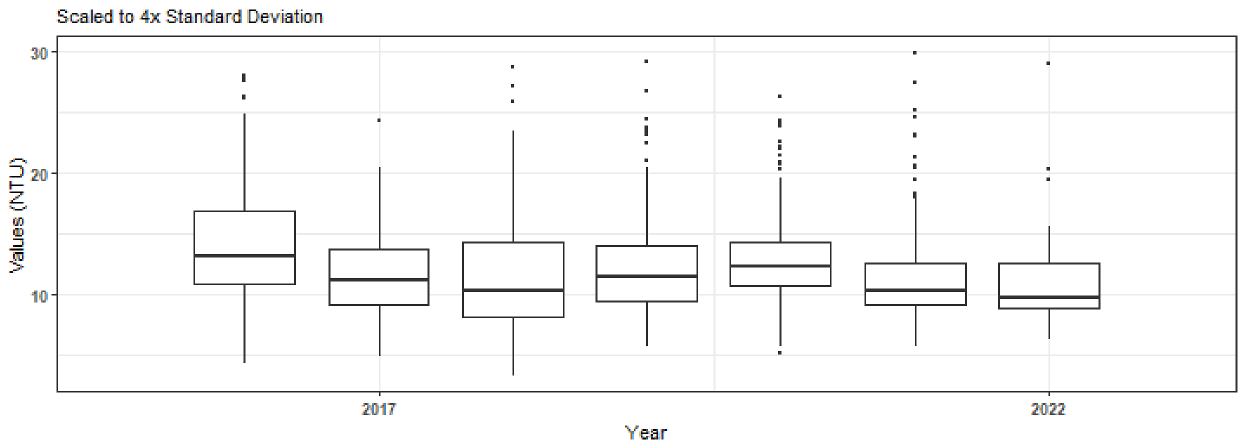
By Month

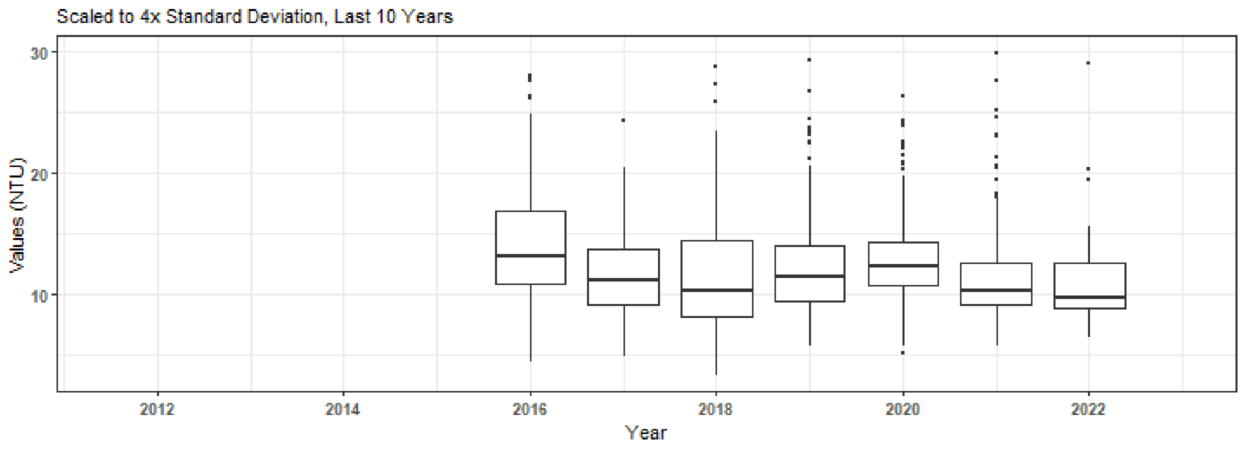


Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbpbwq

By Year

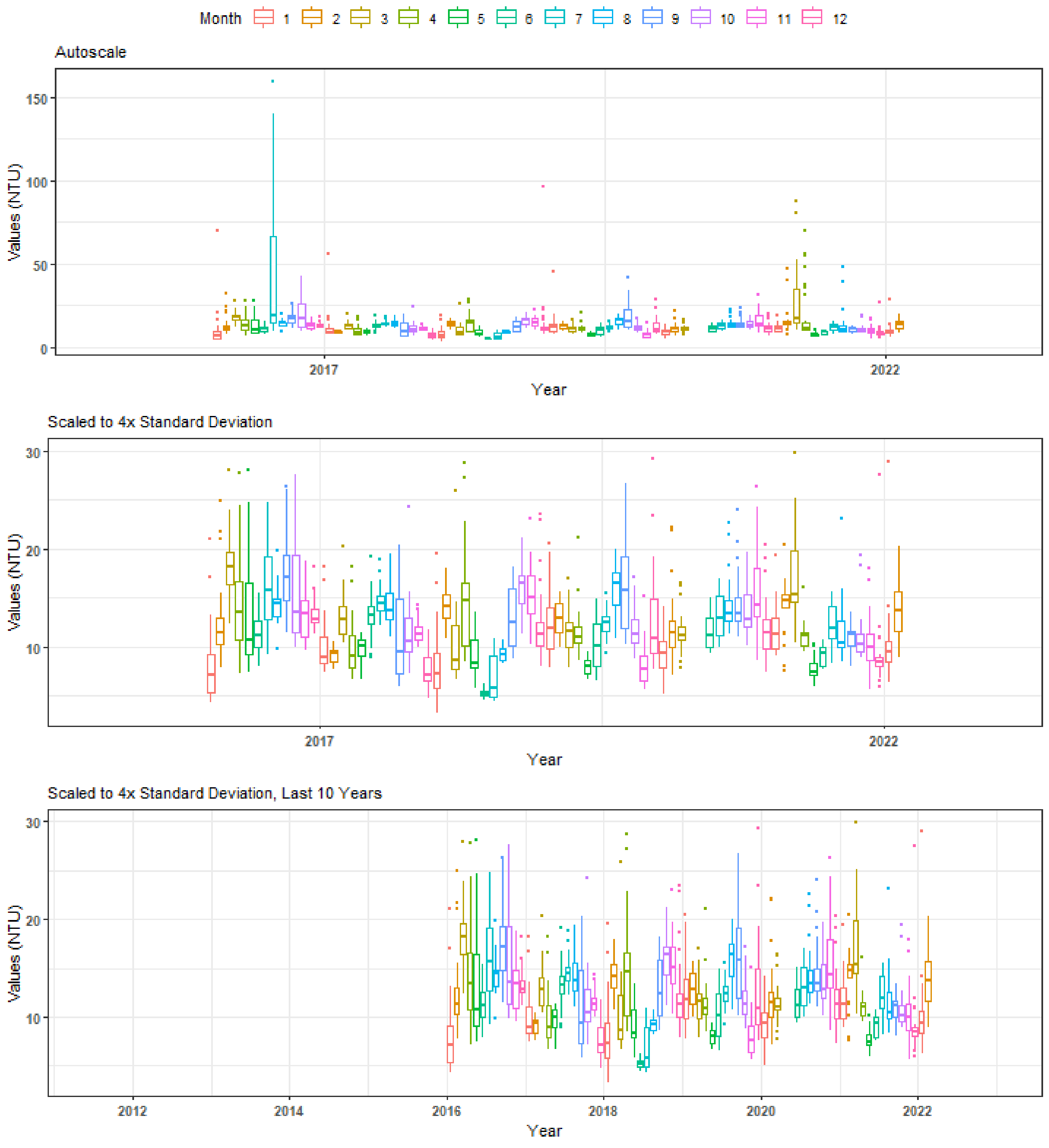






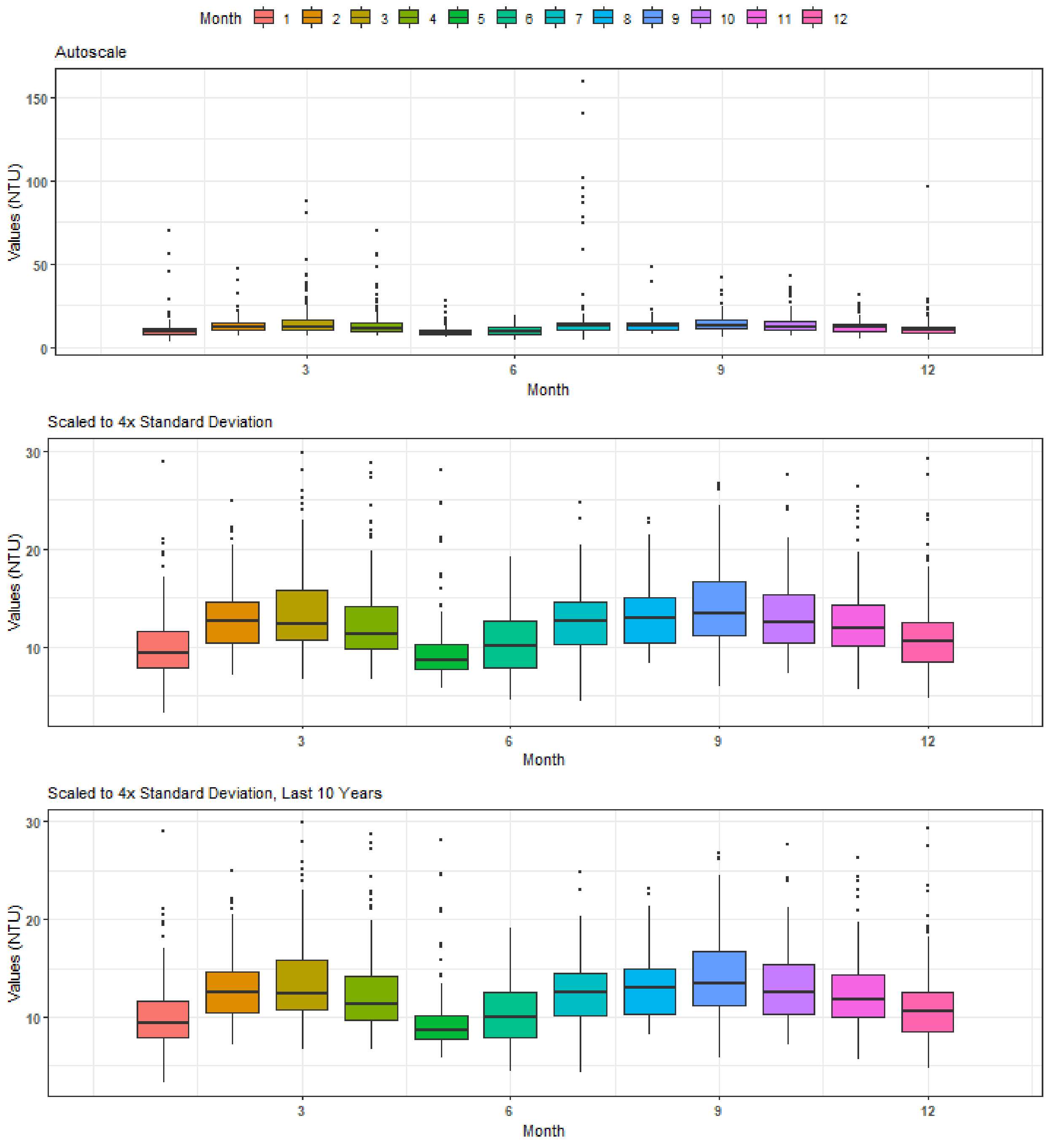
Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbpbwq

By Year & Month



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

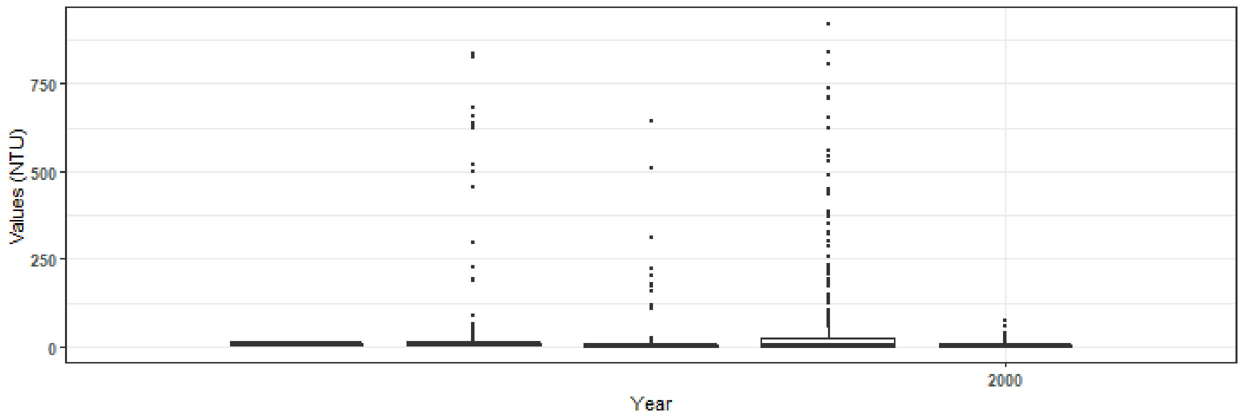
By Month



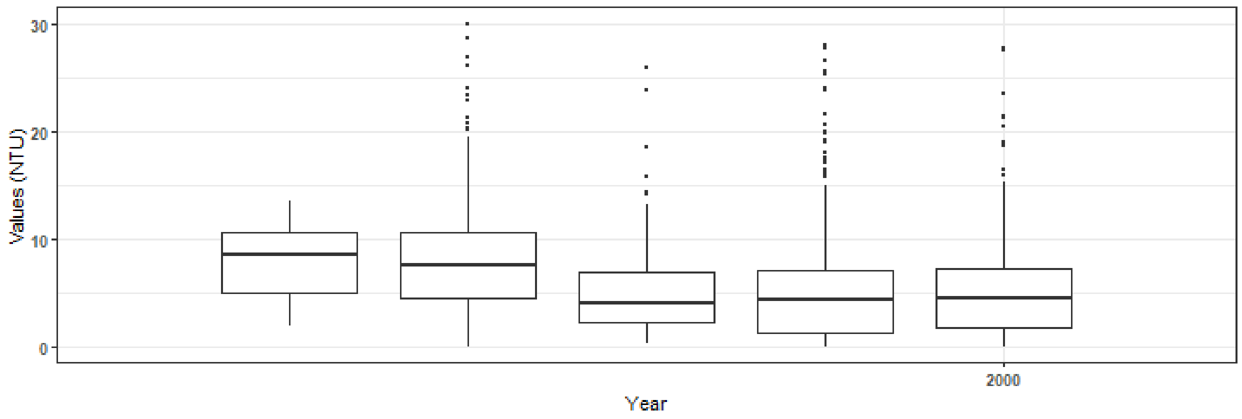
Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbuhwq

By Year

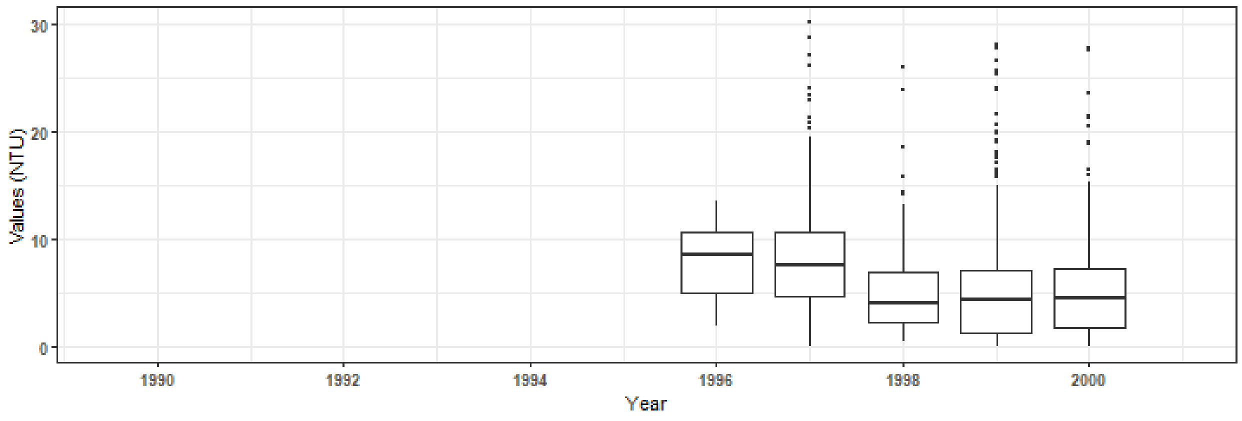
Autoscale



Scaled to 4x Standard Deviation

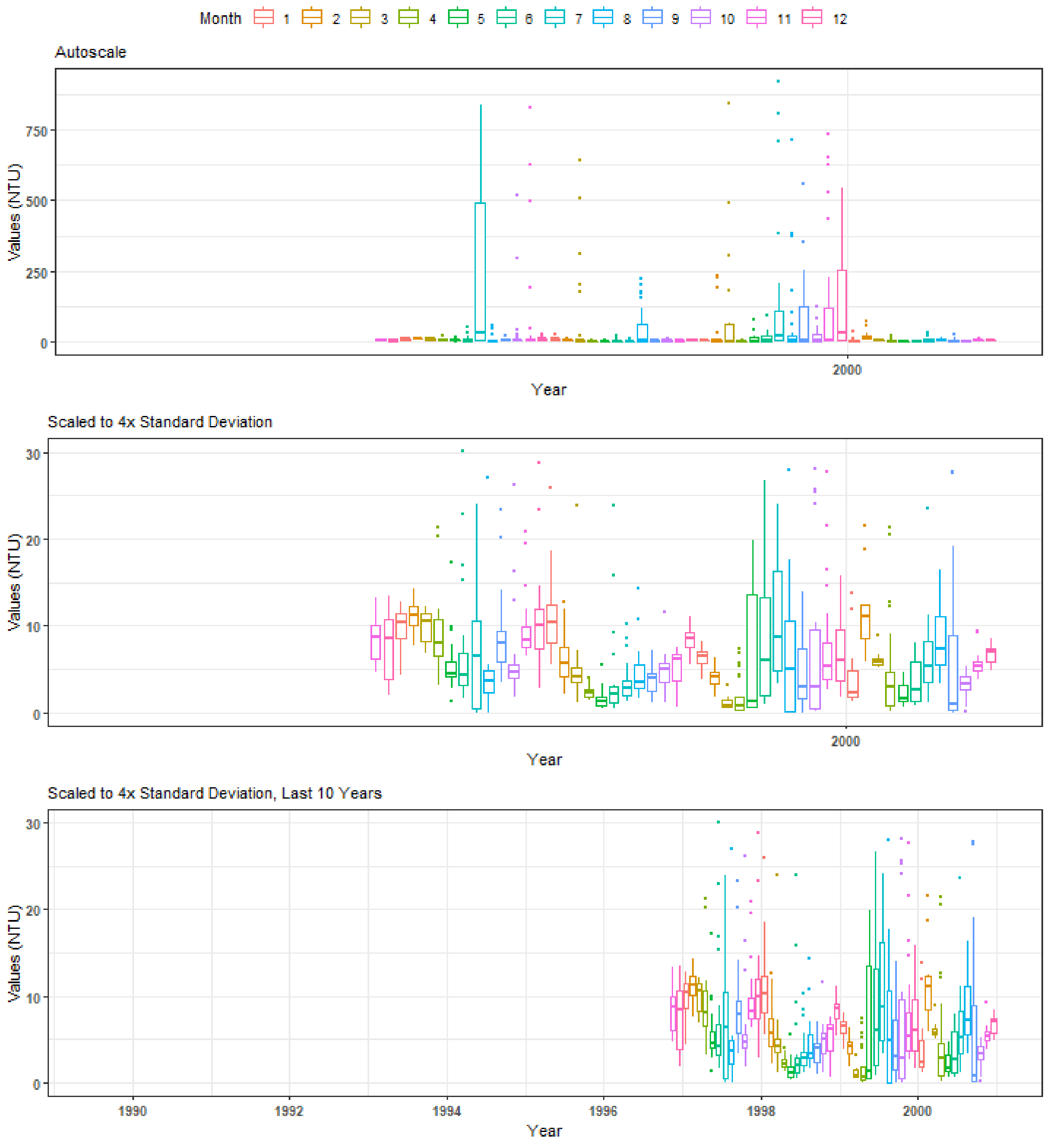


Scaled to 4x Standard Deviation, Last 10 Years



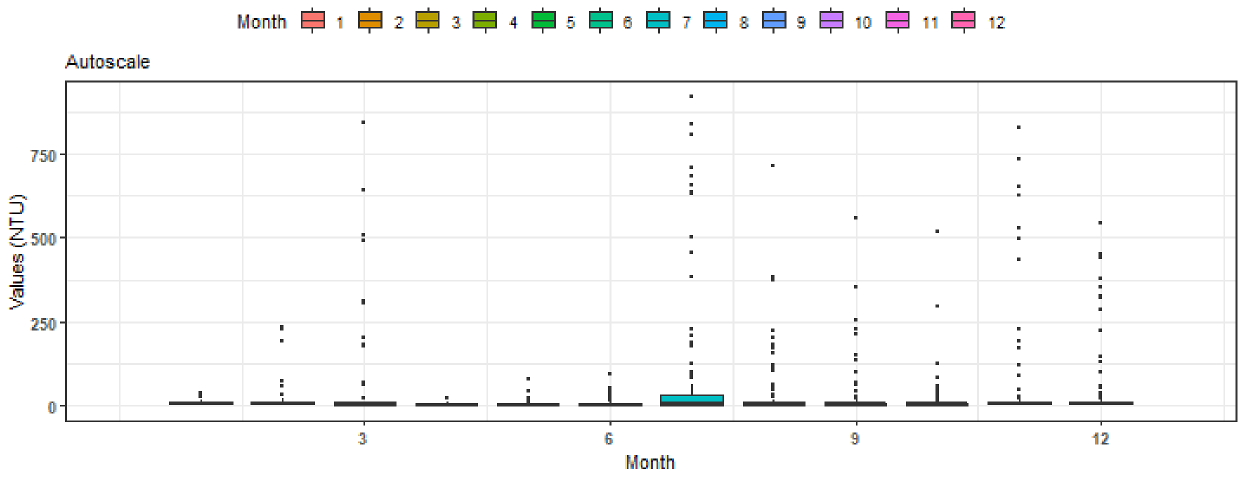
Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbuhwq

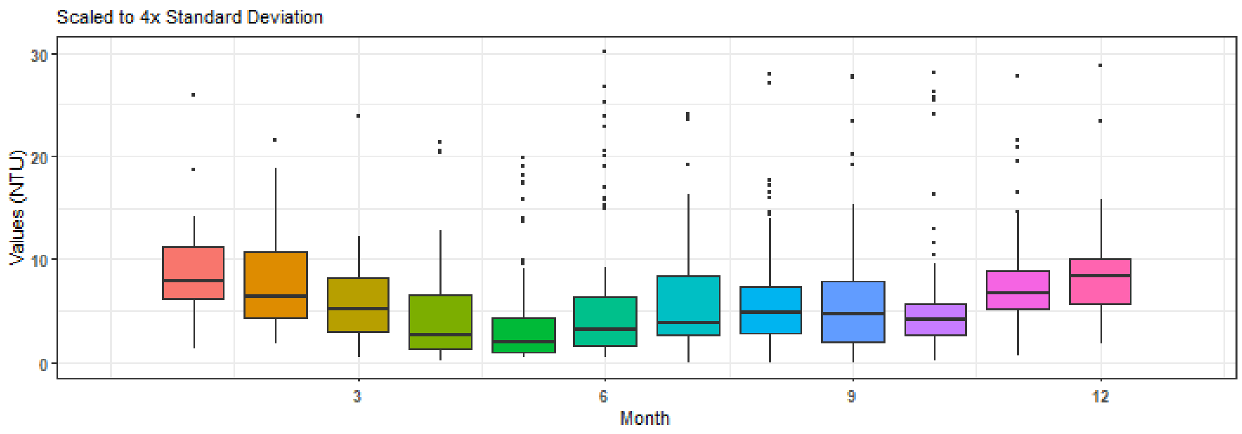
By Year & Month

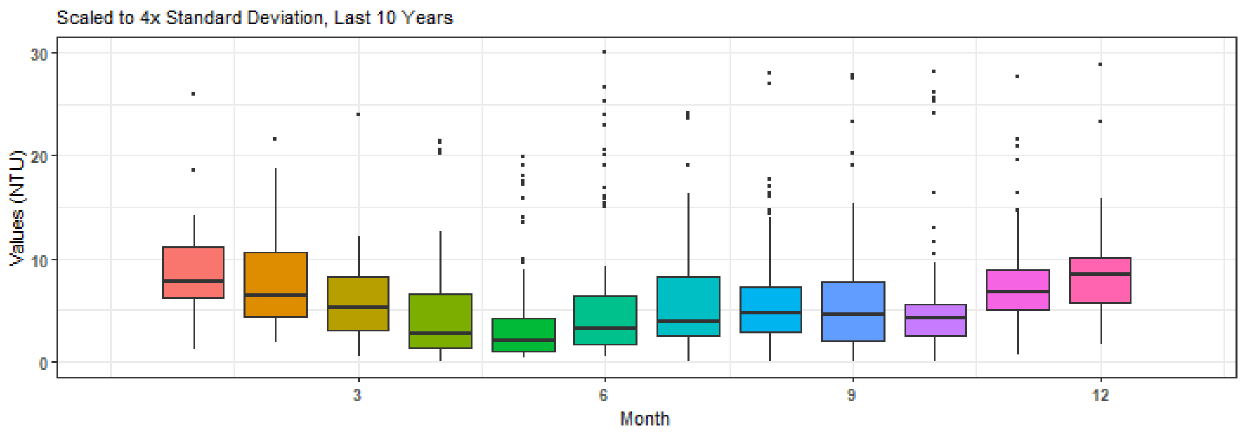


Summary Box Plots for Rookery Bay National Estuarine Research Reserve
354 | Rookery Bay National Estuarine Research Reserve System-Wide Monitoring Program | rkbuhwq

By Month


Month 1 2 3 4 5 6 7 8 9 10 11 12
Autoscale
Values (NTU)
Month


Scaled to 4x Standard Deviation
Values (NTU)
Month


Scaled to 4x Standard Deviation, Last 10 Years
Values (NTU)
Month