

SEACAR Discrete Water Quality Analysis: Field Bottom Dissolved Oxygen

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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)
library(kableExtra)
windowsFonts(`Segoe UI` = windowsFont('Segoe UI'))
options(scipen=999)
opts_chunk$set(warning=FALSE, message=FALSE, dpi=200)
```

File Import

Imports file that is determined in the WC_Discrete_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, units of the parameter, sets the `SampleDate` as a date object, and creates various scales of the date to be used by plotting functions.

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

Data Filtering and Data Impacted by Specific Value Qualifiers

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 only keeps data that is measured at the relative depth (surface, bottom, etc.) and

activity type (field or sample) of interest. This is partly handled on export with the `RelativeDepth` variable, but there are some measurements that are considered both surface and bottom based on measurement depth and total depth. By default, these are marked as `Surface` for `RelativeDepth` and receive a `SEACAR_QAQCFlag` indicator of 12Q. Data passes the filtering process if it is from the correct depth and has an `Include` value of 1. The script also only looks at data of the desired `ActivityType` which indicates whether it was measured in the field (`Field`) or in the lab (`Sample`).

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 10 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.

After filtering, the amount of data impacted by the H (for dissolved oxygen & pH in program 476), I, Q, S (for Secchi depth), and U value qualifiers. A variable is also created that determines if scatter plot points should be a different color based on value qualifiers of interest.

```

if(depth=="Bottom"){
  data$RelativeDepth[grep("12Q", data$SEACAR_QAQCFlagCode[
    data$RelativeDepth=="Surface"])] <- "Bottom"
}

data$Include <- as.logical(data$Include)
data$Include[grep("H", data$ValueQualifier[data$ProgramID==476])] <- TRUE
data <- data[!is.na(data$ResultValue),]

if(param_name!="Secchi_Depth"){
  data <- data[!is.na(data$RelativeDepth),]
  data <- data[data$RelativeDepth==depth,]
}

if(length(grep("Blank", data$ActivityType))>0){
  data <- data[-grep("Blank", data$ActivityType),]
}

if(param_name=="Chlorophyll_a_uncorrected_for_pheophytin" |
  param_name=="Salinity" | param_name=="Turbidity"){
  data <- data[grep(activity, data$ActivityType[!is.na(data$ActivityType)]),]
}

if(param_name=="Water_Temperature"){
  data <- data[data$ResultValue>=-2,]
} else{
  data <- data[data$ResultValue>=0,]
}

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

MA_Summ <- data %>%
  group_by(AreaID, ManagedAreaName) %>%
  summarize(ParameterName=parameter,
            RelativeDepth=depth,
            ActivityType=activity,
            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))

data <- merge.data.frame(data, MA_Summ[,c("ManagedAreaName", "SufficientData")],
                         by="ManagedAreaName")

data$Use_In_Analysis <- ifelse(data$Include==TRUE & data$SufficientData==TRUE,
                                 TRUE, FALSE)

MA_Summ <- MA_Summ %>%
  select(AreaID, ManagedAreaName, ParameterName, RelativeDepth, ActivityType,
         SufficientData, everything())
MA_Summ <- as.data.frame(MA_Summ[order(MA_Summ$ManagedAreaName), ])

total <- length(data$Include)
pass_filter <- length(data$Include[data$Include==TRUE])

count_H <- length(grep("H", data$ValueQualifier[data$ProgramID==476]))
perc_H <- 100*count_H/length(data$ValueQualifier)

count_I <- length(grep("I", data$ValueQualifier))
perc_I <- 100*count_I/length(data$ValueQualifier)

count_Q <- length(grep("Q", data$ValueQualifier))
perc_Q <- 100*count_Q/length(data$ValueQualifier)

count_S <- length(grep("S", data$ValueQualifier))
perc_S <- 100*count_S/length(data$ValueQualifier)

count_U <- length(grep("U", data$ValueQualifier))
perc_U <- 100*count_U/length(data$ValueQualifier)

data$VQ_Plot <- data$ValueQualifier

inc_H <- ifelse(param_name=="pH" | param_name=="Dissolved_Oxygen" |
                  param_name=="Dissolved_Oxygen_Saturation", TRUE, FALSE)

if (inc_H==TRUE){
  data$VQ_Plot <- gsub("[^HU]+", "", data$VQ_Plot)
  data$VQ_Plot <- gsub("UH", "HU", data$VQ_Plot)
  data$VQ_Plot[na.omit(data$ProgramID!=476)] <- gsub("[^U]+", "",
                                                       data$VQ_Plot[na.omit(data$ProgramID!=476)])
  data$VQ_Plot[data$VQ_Plot==""] <- NA}

cat(paste0("Number of Measurements: ", total,
           ", Number Passed Filter: ", pass_filter, "\n",
           "Program 476 H Codes: ", count_H, " (", round(perc_H, 6), "%)\n",
           "I Codes: ", count_I, " (", round(perc_I, 6), "%)\n",

```

```

    "Q Codes: ", count_Q, " (", round(perc_Q, 6), "%)\n",
    "U Codes: ", count_U, " (", round(perc_U, 6), "%))")
} else if (param_name=="Secchi_Depth") {
  count_S <- length(grep("S", data$ValueQualifier))
  perc_S <- 100*count_S/length(data$ValueQualifier)
  data$VQ_Plot <- gsub("[^SU]+", "", data$VQ_Plot)
  data$VQ_Plot <- gsub("US", "SU", data$VQ_Plot)
  data$VQ_Plot[data$VQ_Plot==""] <- NA
  cat(paste0("Number of Measurements: ", total,
             ", Number Passed Filter: ", pass_filter, "\n",
             "I Codes: ", count_I, " (", round(perc_I, 6), "%)\n",
             "Q Codes: ", count_Q, " (", round(perc_Q, 6), "%)\n",
             "S Codes: ", count_S, " (", round(perc_S, 6), "%)\n",
             "U Codes: ", count_U, " (", round(perc_U, 6), "%))")
} else{
  data$VQ_Plot <- gsub("[^U]+", "", data$VQ_Plot)
  data$VQ_Plot[data$VQ_Plot==""] <- NA
  cat(paste0("Number of Measurements: ", total,
             ", Number Passed Filter: ", pass_filter, "\n",
             "I Codes: ", count_I, " (", round(perc_I, 6), "%)\n",
             "Q Codes: ", count_Q, " (", round(perc_Q, 6), "%)\n",
             "U Codes: ", count_U, " (", round(perc_U, 6), "%))")
}

```

```

## Number of Measurements: 172207, Number Passed Filter: 171592
## Program 476 H Codes: 0 (0%)
## I Codes: 0 (0%)
## Q Codes: 0 (0%)
## U Codes: 0 (0%)

```

```

data_summ <- data %>%
  group_by(AreaID, ManagedAreaName) %>%
  summarize(ParameterName=parameter,
            RelativeDepth=depth,
            ActivityType=activity,
            N_Total=length(ResultValue),
            N_AnalysisUse=length(ResultValue[SufficientData==TRUE]),
            N_H=length(grep("H", data$ValueQualifier[data$ProgramID==476])),
            perc_H=100*N_H/length(data$ValueQualifier),
            N_I=length(grep("I", data$ValueQualifier)),
            perc_I=100*N_I/length(data$ValueQualifier),
            N_Q=length(grep("Q", data$ValueQualifier)),
            perc_Q=100*N_Q/length(data$ValueQualifier),
            N_S=length(grep("S", data$ValueQualifier)),
            perc_S=100*N_S/length(data$ValueQualifier),
            N_U=length(grep("U", data$ValueQualifier)),
            perc_U=100*N_U/length(data$ValueQualifier))

data_summ <- as.data.table(data_summ[order(data_summ$ManagedAreaName), ])
fwrite(data_summ, paste0(out_dir, "/", param_name, "_", activity, "_", depth,
                       "_DataSummary.csv"), sep=",")
rm(data_summ)
MA_Include <- MA_Summ$ManagedAreaName[MA_Summ$SufficientData==TRUE &

```

```

MA_Summ$N_Data<2000000]
n <- length(MA_Include)
MA_Exclude <- MA_Summ[MA_Summ$N_Years<10 & MA_Summ$N_Years>0,]
MA_Exclude <- MA_Exclude[,c("ManagedAreaName", "N_Years")]
z <- nrow(MA_Exclude)

```

Managed Area Statistics

Gets summary statistics for each managed area. Excluded managed areas 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 `SufficientData` value of TRUE
2. Group data that have the same `ManagedAreaName`, `Year`, and `Month`.
 - Second summary statistics do not use the `Month` grouping and are only for `ManagedAreaName` and `Year`.
 - Third summary statistics do not use `Year` grouping and are only for `ManagedAreaName` and `Month`
3. For each group, provide the following information: 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` then `Year` then `Month`
5. Write summary stats to a pipe-delimited .txt file in the output directory
 - Click this text to open Git directory with output files

```

MA_YM_Stats <- data[data$Use_In_Analysis==TRUE, ] %>%
  group_by(AreaID, ManagedAreaName, Year, Month) %>%
  summarize(ParameterName=parameter,
            RelativeDepth=depth,
            ActivityType=activity,
            N_Data=length(ResultValue),
            Min=min(ResultValue),
            Max=max(ResultValue),
            Median=median(ResultValue),
            Mean=mean(ResultValue),
            StandardDeviation=sd(ResultValue),
            ProgramIDs=paste(sort(unique(ProgramID), decreasing=FALSE),
                              collapse=', '))
MA_YM_Stats <- as.data.table(MA_YM_Stats[order(MA_YM_Stats$ManagedAreaName,
                                                MA_YM_Stats$Year,
                                                MA_YM_Stats$Month), ])
fwrite(MA_YM_Stats, paste0(out_dir, "/", param_name, "_", activity, "_", depth,
                           "_ManagedArea_YearMonth_Stats.txt"), sep="|")
rm(MA_YM_Stats)

MA_Y_Stats <- data[data$Use_In_Analysis==TRUE, ] %>%
  group_by(AreaID, ManagedAreaName, Year) %>%
  summarize(ParameterName=parameter,
            RelativeDepth=depth,
            ActivityType=activity,
            N=length(ResultValue),

```

```

    Min=min(ResultValue),
    Max=max(ResultValue),
    Median=median(ResultValue),
    Mean=mean(ResultValue),
    StandardDeviation=sd(ResultValue),
    ProgramIDs=paste(sort(unique(ProgramID), decreasing=FALSE),
                      collapse=', '))
MA_Y_Stats <- as.data.table(MA_Y_Stats[order(MA_Y_Stats$ManagedAreaName,
                                              MA_Y_Stats$Year), ])
fwrite(MA_Y_Stats, paste0(out_dir, "/", param_name, "_", activity, "_",
                         "_ManagedArea_Year_Stats.txt"), sep="|")
rm(MA_Y_Stats)

MA_M_Stats <- data[data$Use_In_Analysis==TRUE, ] %>%
  group_by(AreaID, ManagedAreaName, Month) %>%
  summarize(ParameterName=parameter,
            RelativeDepth=depth,
            ActivityType=activity,
            N=length(ResultValue),
            Min=min(ResultValue),
            Max=max(ResultValue),
            Median=median(ResultValue),
            Mean=mean(ResultValue),
            StandardDeviation=sd(ResultValue),
            ProgramIDs=paste(sort(unique(ProgramID), decreasing=FALSE),
                              collapse=', '))
MA_M_Stats <- as.data.table(MA_M_Stats[order(MA_M_Stats$ManagedAreaName,
                                              MA_M_Stats$Month), ])
fwrite(MA_M_Stats, paste0(out_dir, "/", param_name, "_", activity, "_",
                         "_ManagedArea_Month_Stats.txt"), sep="|")
rm(MA_M_Stats)

```

Monitoring Location Statistics

Gets monitoring location statistics, which is defined as a unique combination of `ManagedAreaName`, `ProgramID`, `ProgramAreaName`, and `ProgramLocationID`, using piping from `dplyr` package. The following steps are performed:

1. Take the `data` variable and only include rows that have a `SufficientData` value of TRUE
2. Group data that have the same `ManagedAreaName`, `ProgramID`, `ProgramName`, and `ProgramLocationID`.
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, and Standard Deviation.
4. Sort the data in ascending (A to Z and 0 to 9) order based on `ManagedAreaName` then `ProgramName` then `ProgramID` then `ProgramLocationID`
5. Write summary stats to a pipe-delimited .txt file in the output directory
 - Click this text to open Git directory with output files

```

Mon_Stats <- data[data$Use_In_Analysis==TRUE, ] %>%
  group_by(AreaID, ManagedAreaName, ProgramID, ProgramName, ProgramLocationID) %>%
  summarize(ParameterName=parameter,

```

```

RelativeDepth=depth,
ActivityType=activity,
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_Stats <- as.data.table(Mon_Stats[order(Mon_Stats$ManagedAreaName,
                                             Mon_Stats$ProgramName,
                                             Mon_Stats$ProgramID,
                                             Mon_Stats$ProgramLocationID), ])
fwrite(Mon_Stats, paste0(out_dir, "/", param_name, "_", activity, "_", depth,
                       "_MonitoringLoc_Stats.txt"), sep="|")
rm(Mon_Stats)

```

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 code created by Jason Scolaro that performed at The Water Atlas: <https://sarasota.wateratlas.usf.edu/water-quality-trends/#analysis-overview>

The following steps are performed:

1. Define the functions used in the analysis
2. Check to see if there are any groups to run analysis on.
3. Take the `data` variable and only include rows that have a `SufficientData` value of `TRUE`
4. Group data that have the same `ManagedAreaName`.
5. 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, tau, Senn Slope (`SennSlope`), Senn Intercept (`SennIntercept`), and p.
 - The analysis is run with 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.
6. Reformat columns in the data frame from export.
7. Write summary stats to a pipe-delimited .txt file in the output directory
 - Click this text to open Git directory with output files

```

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$AreaID),
        unique(data$ManagedAreaName),
        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[9])) {
      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$ManagedAreaName
c_names <- c("AreaID", "ManagedAreaName", "Median", "Independent",
           "tau", "p", "SennSlope", "SennIntercept", "Trend")
if(n==0){
  KT$Stats <- data.frame(matrix(ncol=length(c_names),
                                 nrow=length(MA_Summ$ManagedAreaName)))
  colnames(KT$Stats) <- c_names
  KT$Stats[, c("AreaID", "ManagedAreaName")] <-
    MA_Summ[, c("AreaID", "ManagedAreaName")]
} else{
  for (i in 1:n) {
    x <- nrow(data[data$Use_In_Analysis == TRUE &
                  data$ManagedAreaName == MA_Include[i], ])
    if (x>0) {
      KT$Stats <- runStats(data[data$Use_In_Analysis == TRUE &
                                data$ManagedAreaName ==
                                MA_Include[i], ])
    }
  }
}

```

```

    }

KT.Stats <- as.data.frame(KT.Stats)
c_names <- c("AreaID", "ManagedAreaName", "Median", "Independent",
           "tau", "p", "SennSlope", "SennIntercept", "Trend")
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(MA_Summ, KT.Stats,
                             by=c("AreaID", "ManagedAreaName"), all=TRUE)

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

fwrite(KT.Stats, paste0(out_dir, "/", param_name, "_", activity, "_", depth,
                      "_KendallTau_Stats.txt"), sep="|")
data <- data[!is.na(data$ResultValue), ]

```

Appendix I: Scatter Plot of Entire Dataset

This part will create a scatter plot of the all data that passed initial filtering criteria with points colored based on specific value qualifiers. The values determined at the beginning (`year_lower`, `year_upper`, `min_RV`, `mn_RV`, `x_scale`, and `y_scale`) are solely for use by the plotting functions and are not output as part of the computed statistics.

```

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.title.x = element_text(margin = margin(t = 5, r = 0,
                                                    b = 10, l = 0)),
        axis.title.y = element_text(margin = margin(t = 0, r = 10,
                                                    b = 0, l = 0)),
        axis.text=element_text(size=10),
        axis.text.x=element_text(face="bold", angle = 60, hjust = 1),
        axis.text.y=element_text(face="bold"))

year_lower <- min(data$Year)
year_upper <- max(data$Year)
min_RV <- min(data$ResultValue)
mn_RV <- mean(data$ResultValue[data$ResultValue <
                                quantile(data$ResultValue, 0.98)])
sd_RV <- sd(data$ResultValue[data$ResultValue <
                                quantile(data$ResultValue, 0.98)])

```

```

x_scale <- ifelse(year_upper - year_lower > 30, 10, 5)
y_scale <- mn_RV + 4 * sd_RV

p1 <- ggplot(data=data[data$Include==TRUE,],
              aes(x=SampleDate, y=ResultValue, fill=VQ_Plot)) +
  geom_point(shape=21, size=3, color="#333333", alpha=0.75) +
  labs(subtitle="Autoscale",
       x="Year", y=paste0("Values (", unit, ")"),
       fill="Value Qualifier") +
  plot_theme +
  theme(legend.position="top", legend.box="horizontal",
        legend.justification="right") +
  scale_x_date(labels=date_format("%Y")) +
  {if(inc_H==TRUE){
    scale_fill_manual(values=c("H"= "#F8766D", "U"= "#00BFC4",
                               "HU"="#7CAE00"), na.value="#cccccc")
  } else if(param_name=="Secchi_Depth"){
    scale_fill_manual(values=c("S"= "#F8766D", "U"= "#00BFC4",
                               "SU"="#7CAE00"), na.value="#cccccc")
  } else {
    scale_fill_manual(values=c("U"= "#00BFC4"), na.value="#cccccc")
  }}
}

p2 <- ggplot(data=data[data$Include==TRUE,],
              aes(x=SampleDate, y=ResultValue, fill=VQ_Plot)) +
  geom_point(shape=21, size=3, color="#333333", alpha=0.75) +
  ylim(min_RV, y_scale) +
  labs(subtitle="Scaled to 4x Standard Deviation",
       x="Year", y=paste0("Values (", unit, ")")) +
  plot_theme +
  theme(legend.position="none") +
  scale_x_date(labels=date_format("%Y")) +
  {if(inc_H==TRUE){
    scale_fill_manual(values=c("H"= "#F8766D", "U"= "#00BFC4",
                               "HU"="#7CAE00"), na.value="#cccccc")
  } else if(param_name=="Secchi_Depth"){
    scale_fill_manual(values=c("S"= "#F8766D", "U"= "#00BFC4",
                               "SU"="#7CAE00"), na.value="#cccccc")
  } else {
    scale_fill_manual(values=c("U"= "#00BFC4"), na.value="#cccccc")
  }}
}

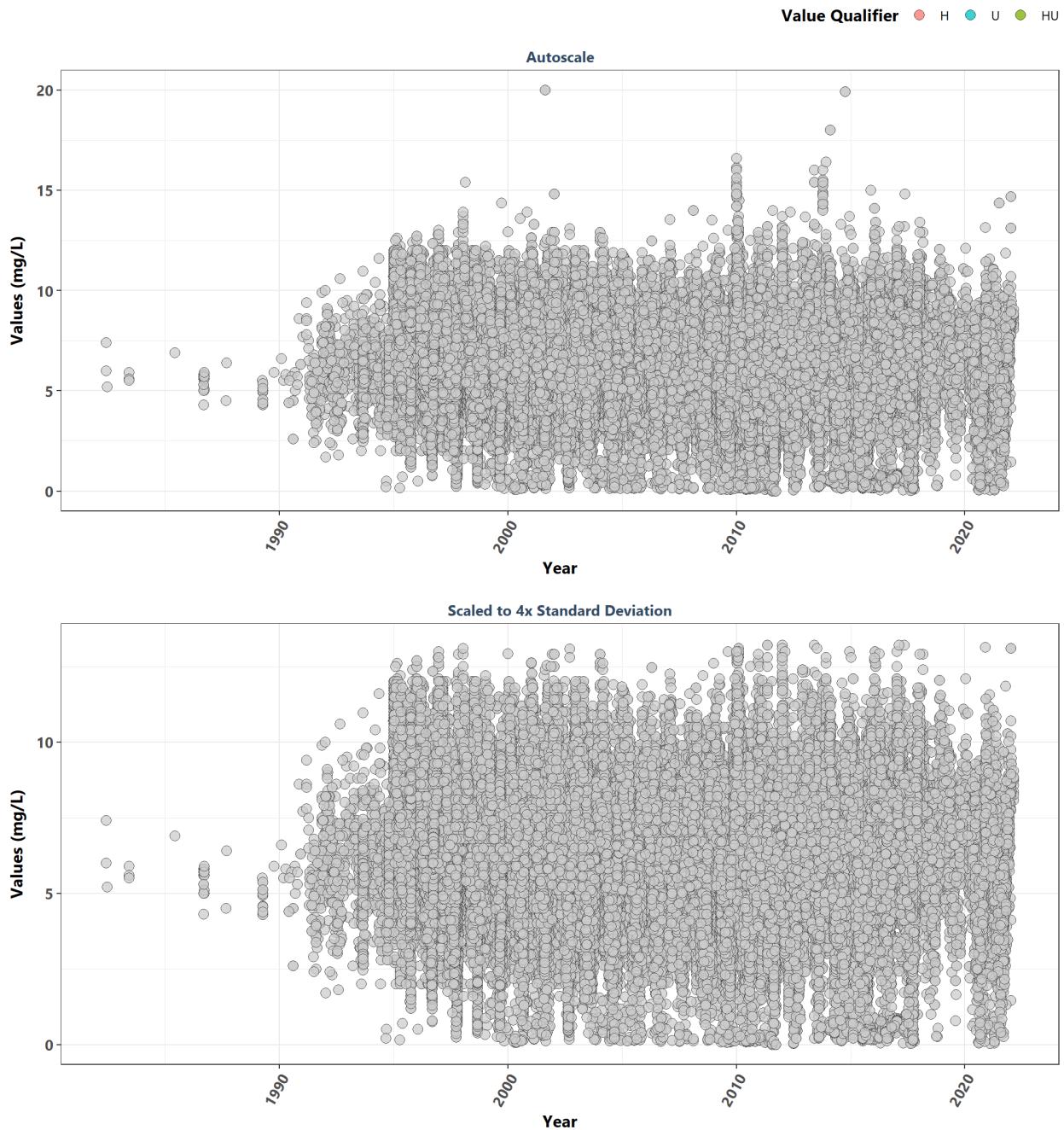
leg <- get_legend(p1)
pset <- ggarrange(leg, p1 + theme(legend.position="none"), p2,
                  ncol=1, heights=c(0.1, 1, 1))

p0 <- ggplot() + labs(title="Scatter Plot for Entire Dataset") +
  plot_theme + theme(panel.border=element_blank(),
                     panel.grid.major=element_blank(),
                     panel.grid.minor=element_blank(),
                     axis.line=element_blank())

```

```
ggarrange(p0, pset, ncol=1, heights=c(0.1, 1))
```

Scatter Plot for Entire Dataset



Appendix II: 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 `SufficientData` 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(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(min_RV, y_scale) +
  plot_theme

p3 <- ggplot(data=data[data$Include==TRUE, ],
              aes(x=as.integer(Year), y=ResultValue, group=Year)) +
  geom_boxplot(color="#333333", fill="#cccccc", outlier.shape=21,
               outlier.size=3, outlier.color="#333333",
               outlier.fill="#cccccc", outlier.alpha=0.75) +
  labs(subtitle="Scaled to 4x Standard Deviation, Last 10 Years",
       x="Year", y=paste0("Values (", unit, ")")) +
  ylim(min_RV, y_scale) +
  scale_x_continuous(limits=c(max(data$Year) - 10.5, max(data$Year)+1),
```

```

            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 4x Standard Deviation",
     x="Year", y=paste0("Values (", unit, ")")) +
ylim(min_RV, y_scale) +
plot_theme +
theme(legend.position="none", axis.text.x=element_text(face="bold"),
      axis.text.y=element_text(face="bold"))

p3 <- ggplot(data=data[data$Include==TRUE, ],
              aes(x=YearMonthDec, y=ResultValue,
                  group=YearMonth, color=as.factor(Month))) +
geom_boxplot(fill="#cccccc", outlier.size=1.5, outlier.alpha=0.75) +
labs(subtitle="Scaled to 4x Standard Deviation, Last 10 Years",
     x="Year", y=paste0("Values (", unit, ")")) +
ylim(min_RV, y_scale) +
scale_x_continuous(limits=c(max(data$Year) - 10.5, max(data$Year)+1),
                   breaks=seq(max(data$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())

```

```

  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 4x Standard Deviation",
       x="Month", y=paste0("Values (", unit, ")")) +
  ylim(min_RV, y_scale) +
  scale_x_continuous(limits=c(0, 13), breaks=seq(3, 12, 3)) +
  plot_theme +
  theme(legend.position="none")

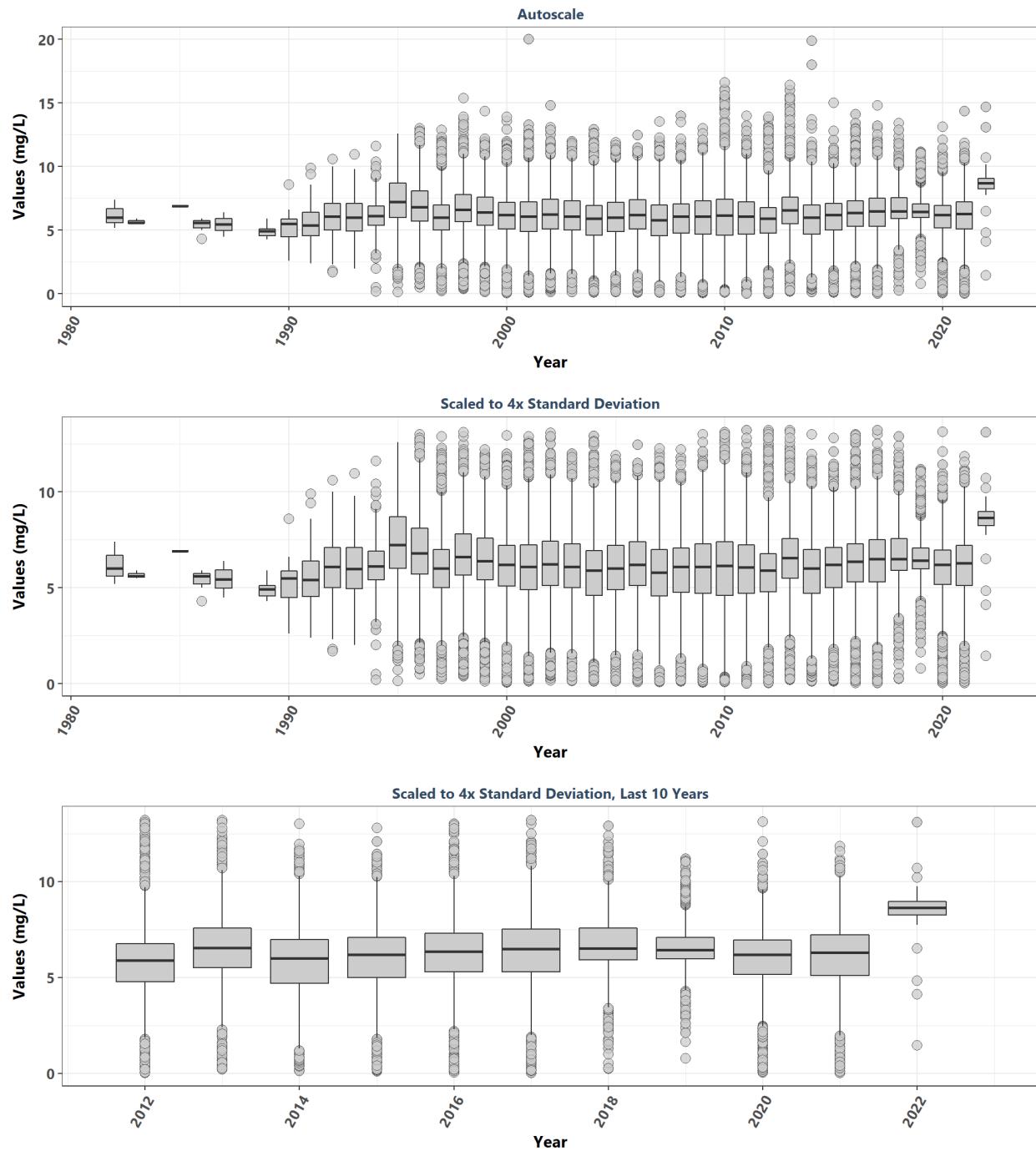
p3 <- ggplot(data=data[data$Include==TRUE &
                           data$Year >= max(data$Year) - 10, ],
              aes(x=Month, y=ResultValue,
                  group=Month, fill=as.factor(Month))) +
  geom_boxplot(color="#333333", outlier.shape=21, outlier.size=3,
               outlier.color="#333333", outlier.alpha=0.75) +
  labs(subtitle="Scaled to 4x Standard Deviation, Last 10 Years",
       x="Month", y=paste0("Values (", unit, ")")) +
  ylim(min_RV, 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())

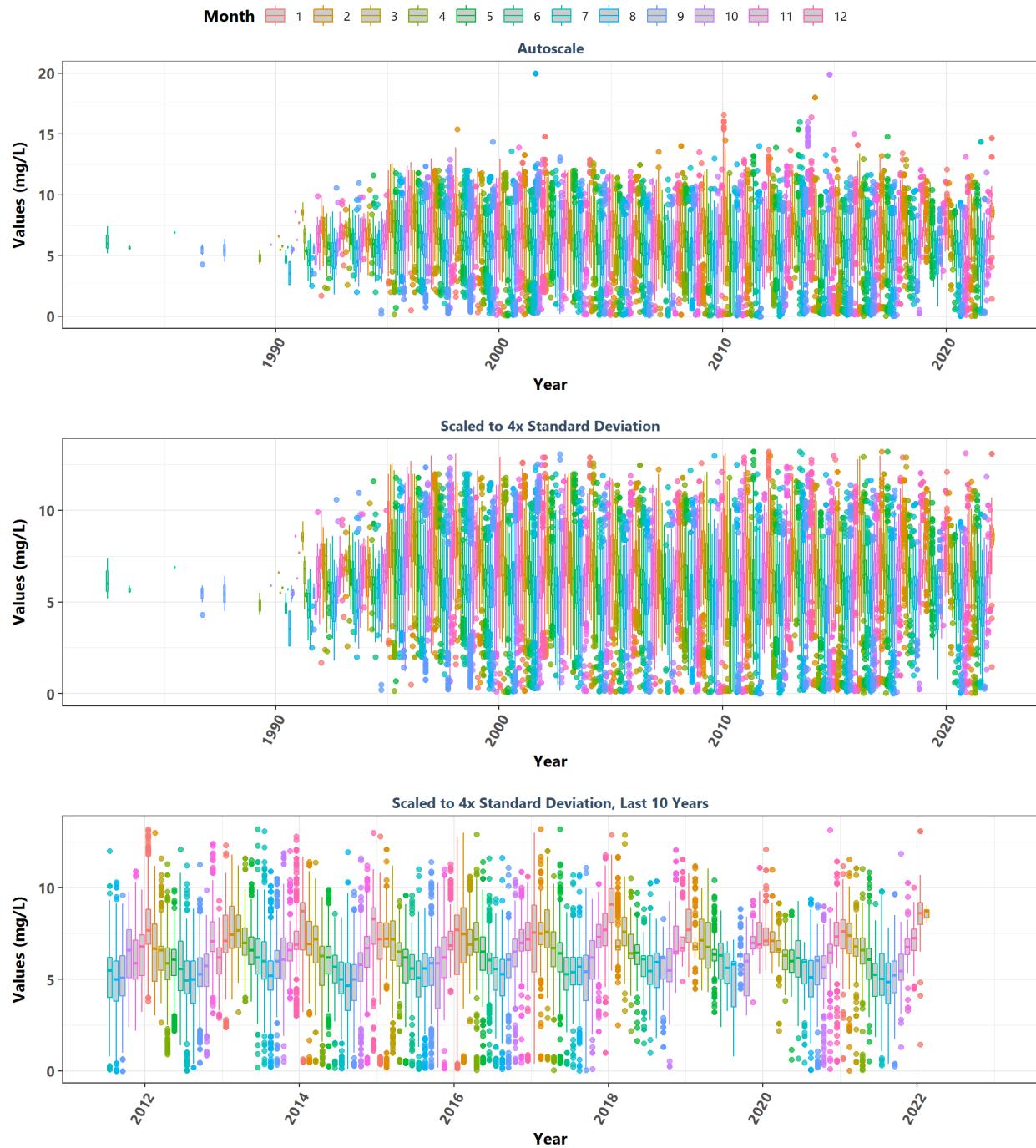
Mset <- ggarrange(p0, set, ncol=1, heights=c(0.07, 1))

```

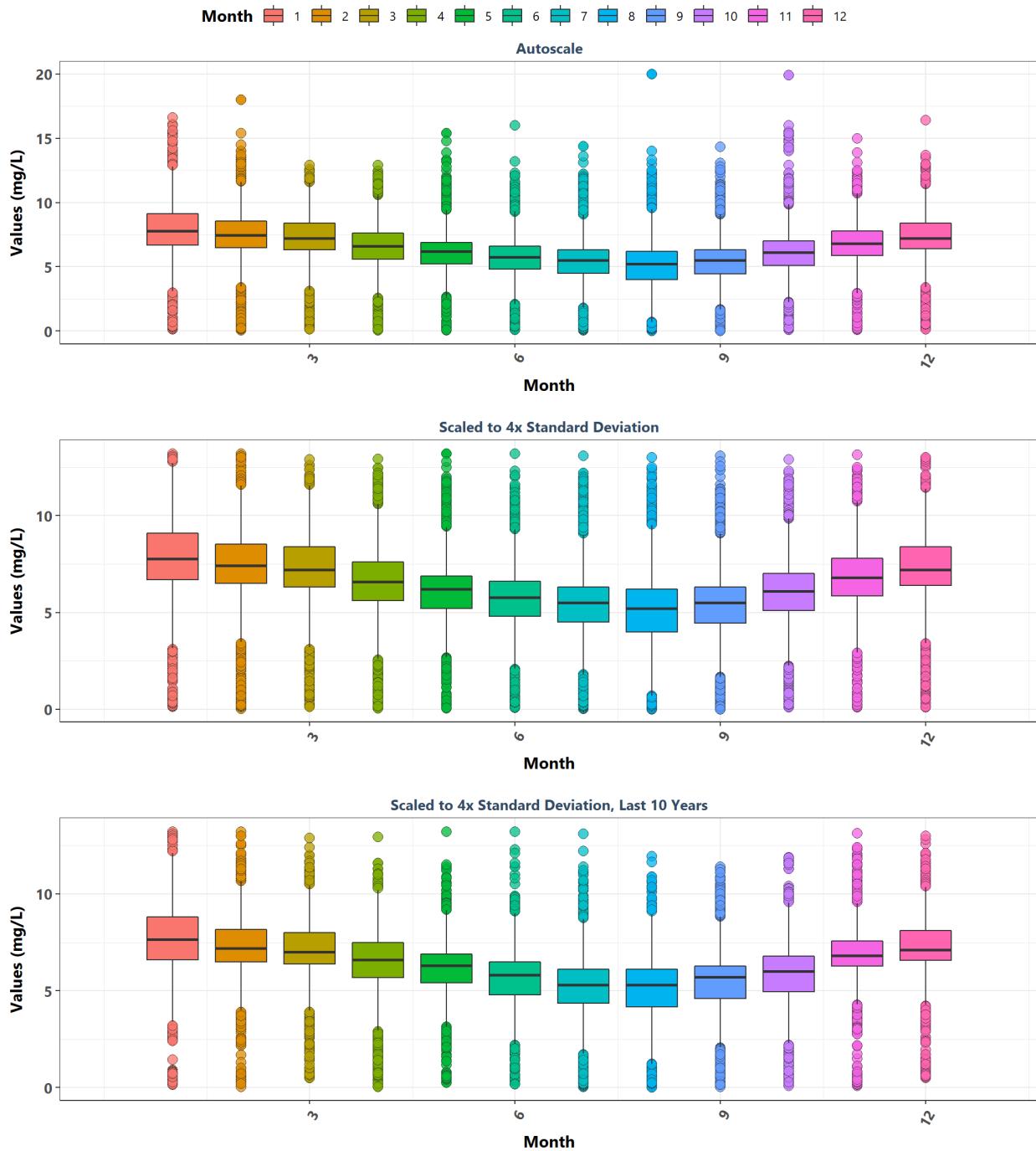
Summary Box Plots for Entire Data
By Year



Summary Box Plots for Entire Data
By Year & Month



Summary Box Plots for Entire Data
By Month



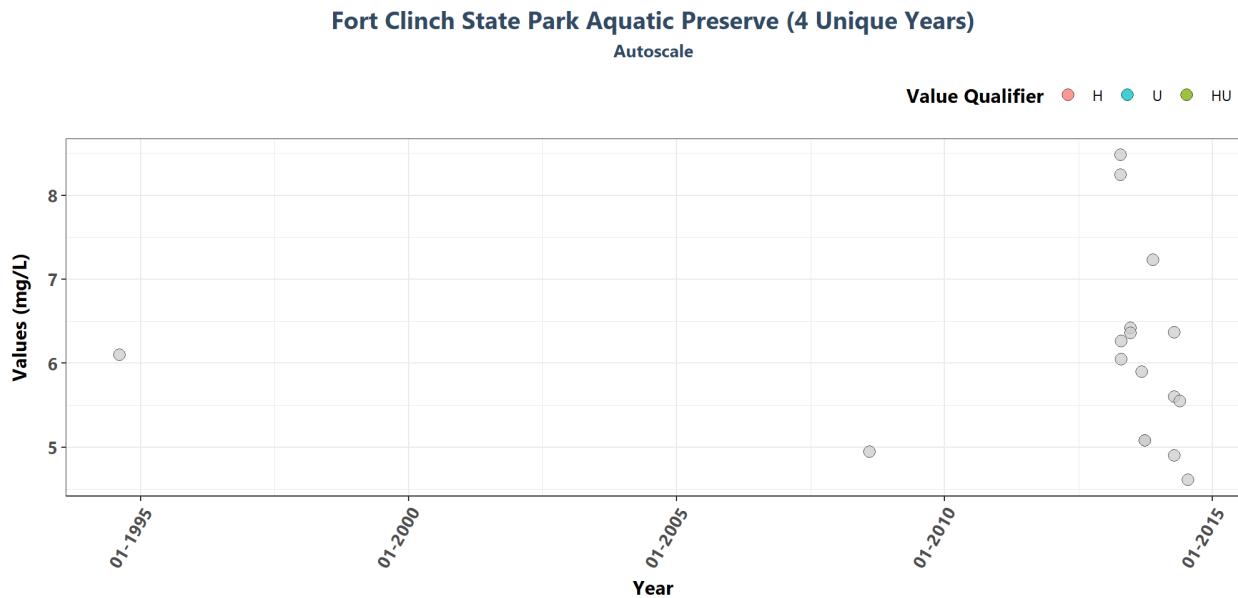
Appendix III: Excluded Managed Areas

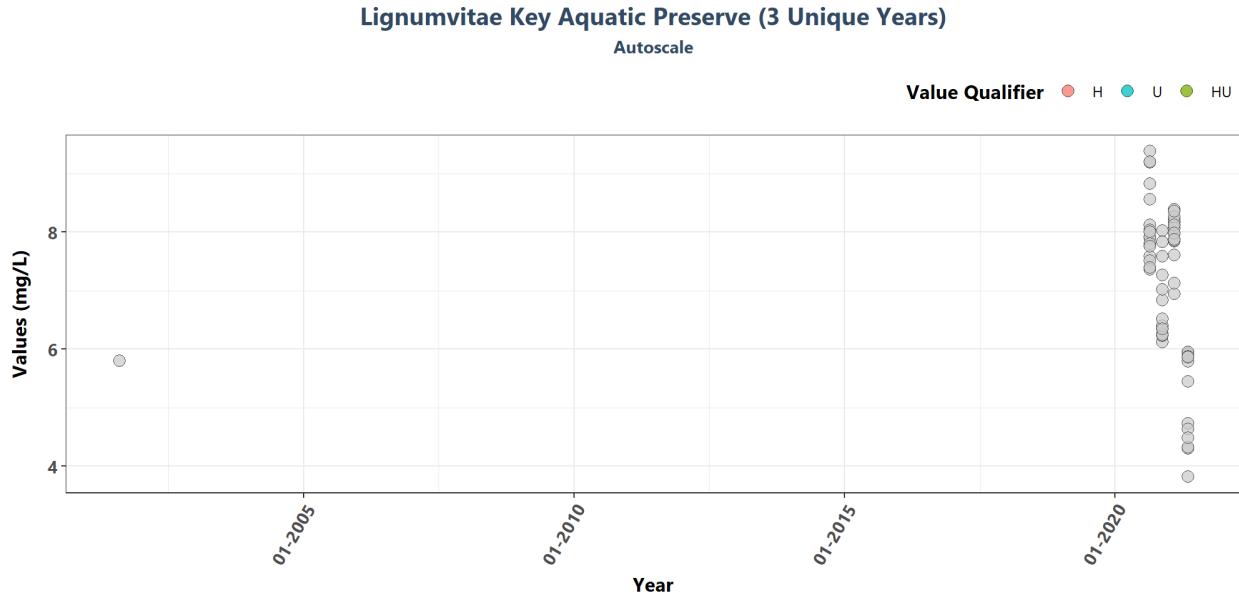
Scatter plots of data values are created for managed areas that have fewer than 10 separate years of data entries. Data points are colored based on specific value qualifiers of interest.

```

if(z==0){
  print("There are no managed areas that qualify.")
} else {
  for(i in 1:z){
    p1<-ggplot(data=data[data$ManagedAreaName==MA_Exclude$ManagedAreaName[i]&
      data$Include==TRUE, ],
      aes(x=SampleDate, y=ResultValue, fill=VQ_Plot)) +
      geom_point(shape=21, size=3, color="#333333", alpha=0.75) +
      labs(title=paste0(MA_Exclude$ManagedAreaName[i], " (",
        MA_Exclude$N_Years[i], " Unique Years")),
        subtitle="Autoscale", x="Year",
        y=paste0("Values (", unit, ")"), fill="Value Qualifier") +
      plot_theme +
      theme(legend.position="top", legend.box="horizontal",
        legend.justification="right") +
      scale_x_date(labels=date_format("%m-%Y")) +
      {if(inc_H==TRUE){
        scale_fill_manual(values=c("H"= "#F8766D", "U"= "#00BFC4",
          "HU"="#7CAE00"), na.value="#cccccc")
      } else if(param_name=="Secchi_Depth"){
        scale_fill_manual(values=c("S"= "#F8766D", "U"= "#00BFC4",
          "SU"="#7CAE00"), na.value="#cccccc")
      } else {
        scale_fill_manual(values=c("U"= "#00BFC4"), na.value="#cccccc")
      }
      print(p1)
    }
  }
}

```





Appendix IV: Managed Area Trendlines

The plots created in this section are designed to show the general trend of the data. Data is taken and grouped by `ManagedAreaName`. 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 `SufficientData` of TRUE for the desired managed area
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 managed areas that qualify.")
} else {
  for (i in 1:n) {
    plot_data <- data[data$SufficientData==TRUE &
                      data$ManagedAreaName==MA_Include[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$ResultValue <
      quantile(data$ResultValue, 0.98)])
  }
}
```

```

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

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

model <- lm(ResultValue ~ DecDate,
            data=plot_data)
m_int <- coef(model)[[1]]
m_slope <- coef(model)[[2]]
rm(model)
p1 <- ggplot(data=plot_data,
              aes(x=DecDate, y=ResultValue, fill=VQ_Plot)) +
  geom_point(shape=21, size=3, color="#333333", 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, ")"),
       fill="Value Qualifier") +
  plot_theme +
  theme(legend.position="top", legend.box="horizontal",
        legend.justification="right") +
  {if(inc_H==TRUE){
    scale_fill_manual(values=c("H"= "#F8766D", "U"= "#00BFC4",
                               "HU"= "#7CAE00"), na.value="#cccccc")
  } else if(param_name=="Secchi_Depth"){
    scale_fill_manual(values=c("S"= "#F8766D", "U"= "#00BFC4",
                               "SU"= "#7CAE00"), na.value="#cccccc")
  } else {
    scale_fill_manual(values=c("U"= "#00BFC4"), na.value="#cccccc")
  }}
}

p2 <- ggplot(data=plot_data,
              aes(x=DecDate, y=ResultValue, fill=VQ_Plot)) +
  geom_point(shape=21, size=3, color="#333333", alpha=0.75) +
  geom_abline(aes(slope=s_slope, intercept=s_int),
              color="#000099", size=1.2, alpha=0.7) +
  ylim(min_RV, y_scale) +
  labs(subtitle="Scaled to 4x Standard Deviation",
       x="Year", y=paste0("Values (", unit, ")")) +
  plot_theme +
  theme(legend.position="none") +
  {if(inc_H==TRUE){
    scale_fill_manual(values=c("H"= "#F8766D", "U"= "#00BFC4",
                               "HU"= "#7CAE00"), na.value="#cccccc")
  } else if(param_name=="Secchi_Depth"){
    scale_fill_manual(values=c("S"= "#F8766D", "U"= "#00BFC4",
                               "SU"= "#7CAE00"), na.value="#cccccc")
  }
}

```

```

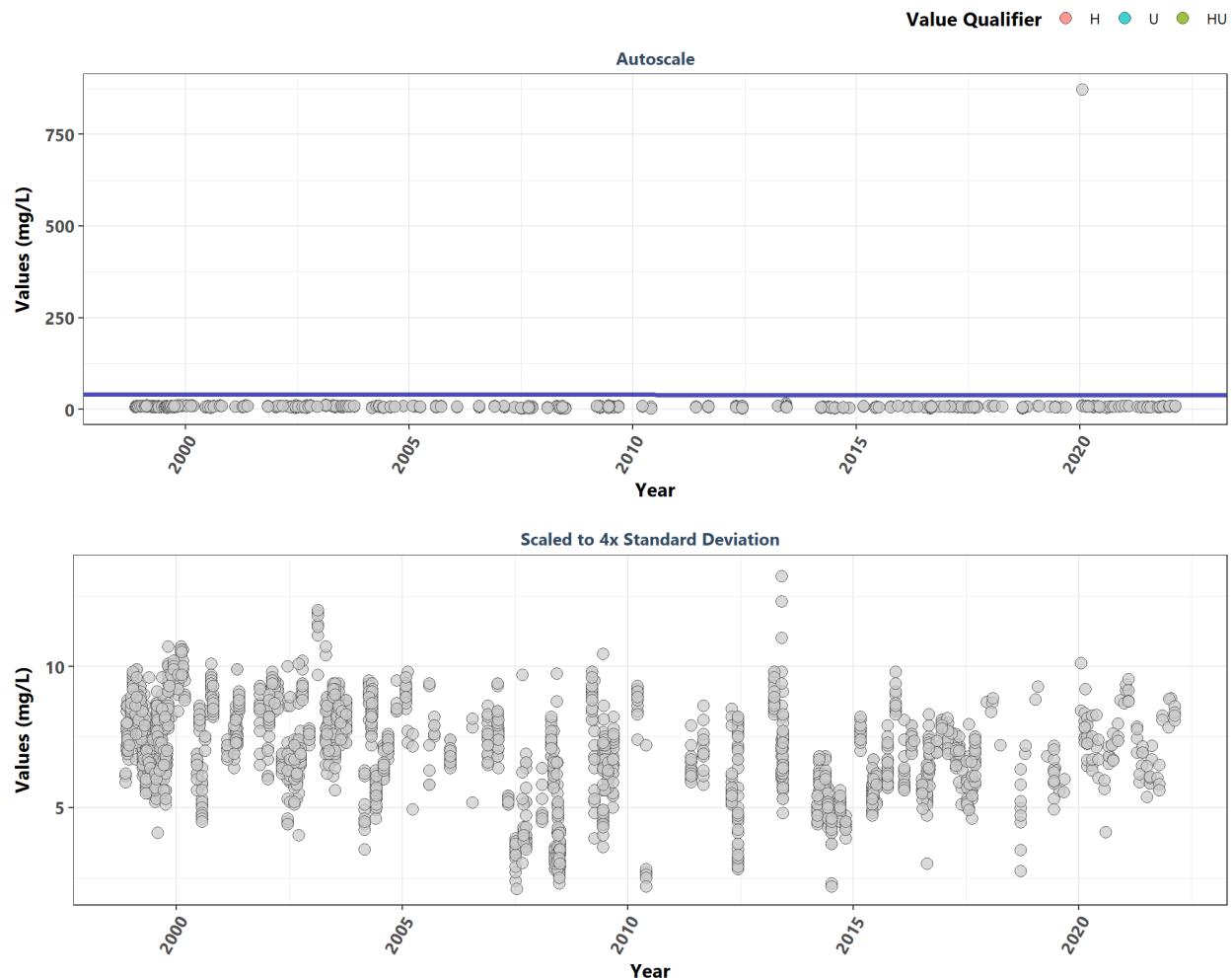
} else {
  scale_fill_manual(values=c("U"= "#00BFC4"), na.value="#cccccc")
}
leg <- get_legend(p1)
KTset <- ggarrange(leg, p1 + theme(legend.position="none"), p2,
                    ncol=1, heights=c(0.1, 1, 1))

p0 <- ggplot() + labs(title=paste0(MA_Include[i])) +
  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(0.1, 1)))
cat('\n')
print(KT$Stats[KT$Stats$ManagedAreaName==MA_Include[i], ] %>%
  select(N_Data, Median, tau, SennSlope, SennIntercept, p, Trend) %>%
  kable(format="latex") %>%
  row_spec(0, bold=TRUE) %>%
  kable_styling(latex_options = "HOLD_position") %>%
  add_footnote(
    "p < 0.00005 appear as 0 due to rounding"))
cat('\n')
rm(plot_data)
rm(KTset, leg)
}
}

```

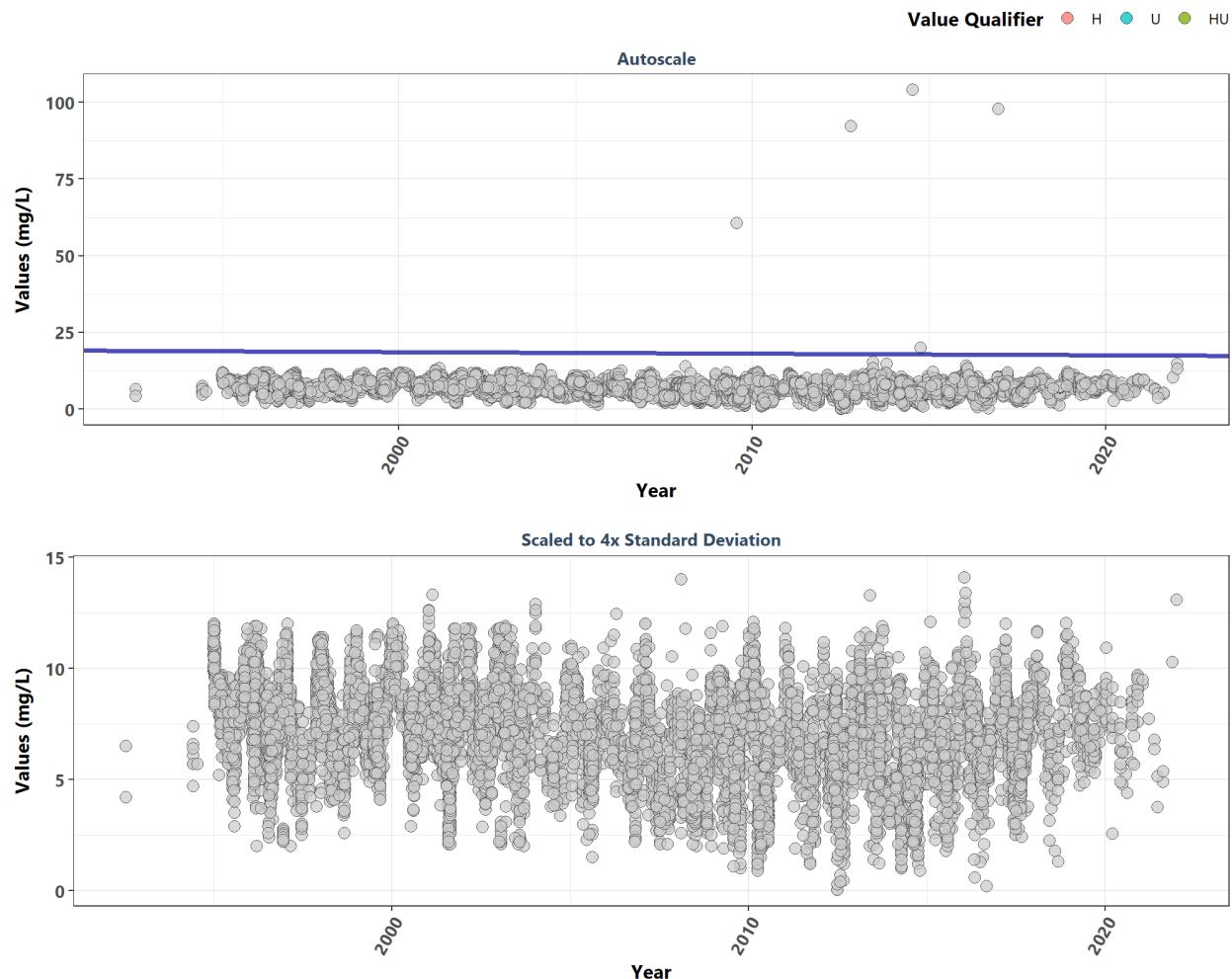
Alligator Harbor Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
2492	7.1	-0.151	-0.0466667	133.8267	0	-1

^a p < 0.00005 appear as 0 due to rounding

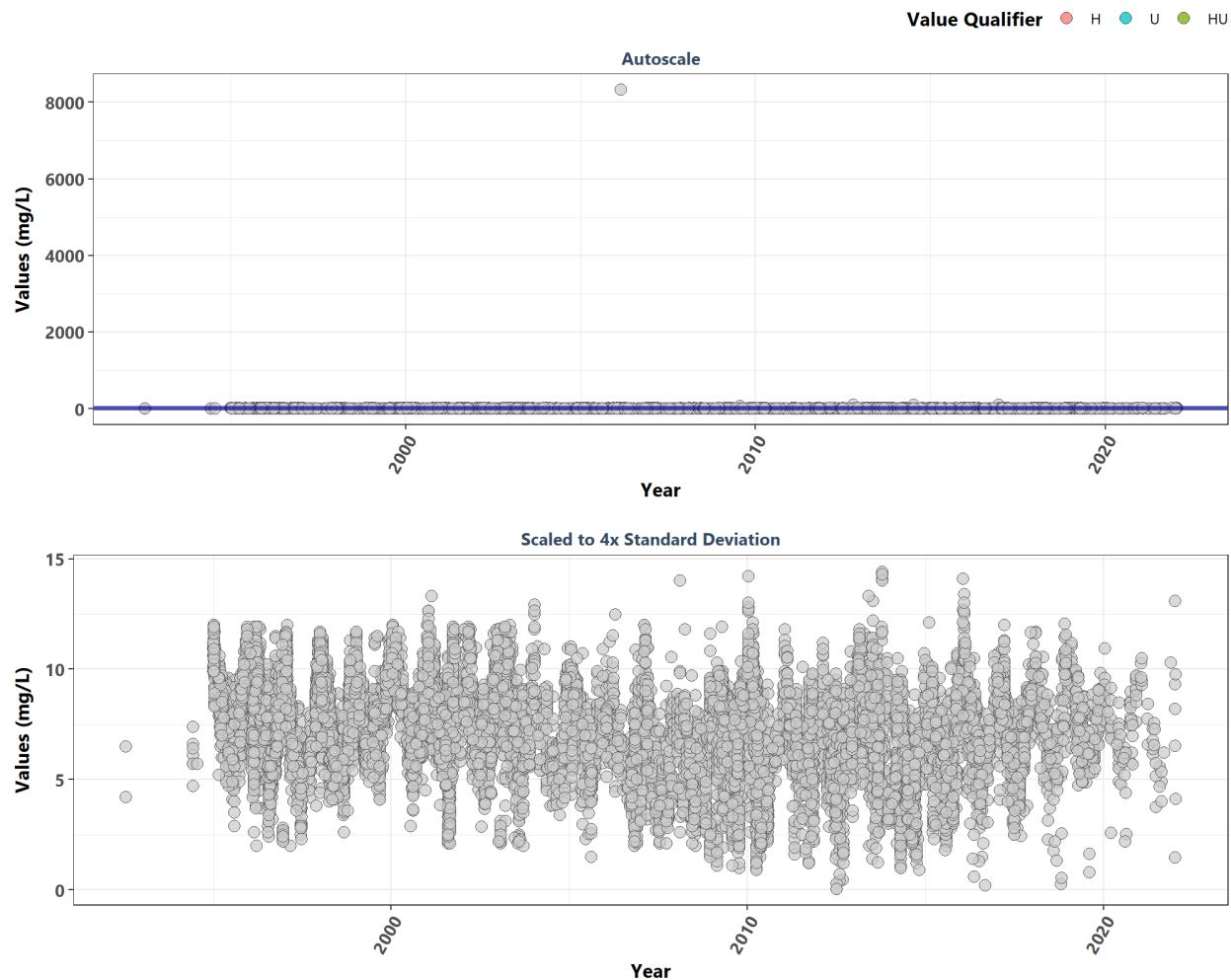
Apalachicola Bay Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
11652	7	-0.145	-0.0511111	120.8935	0	-1

^a p < 0.00005 appear as 0 due to rounding

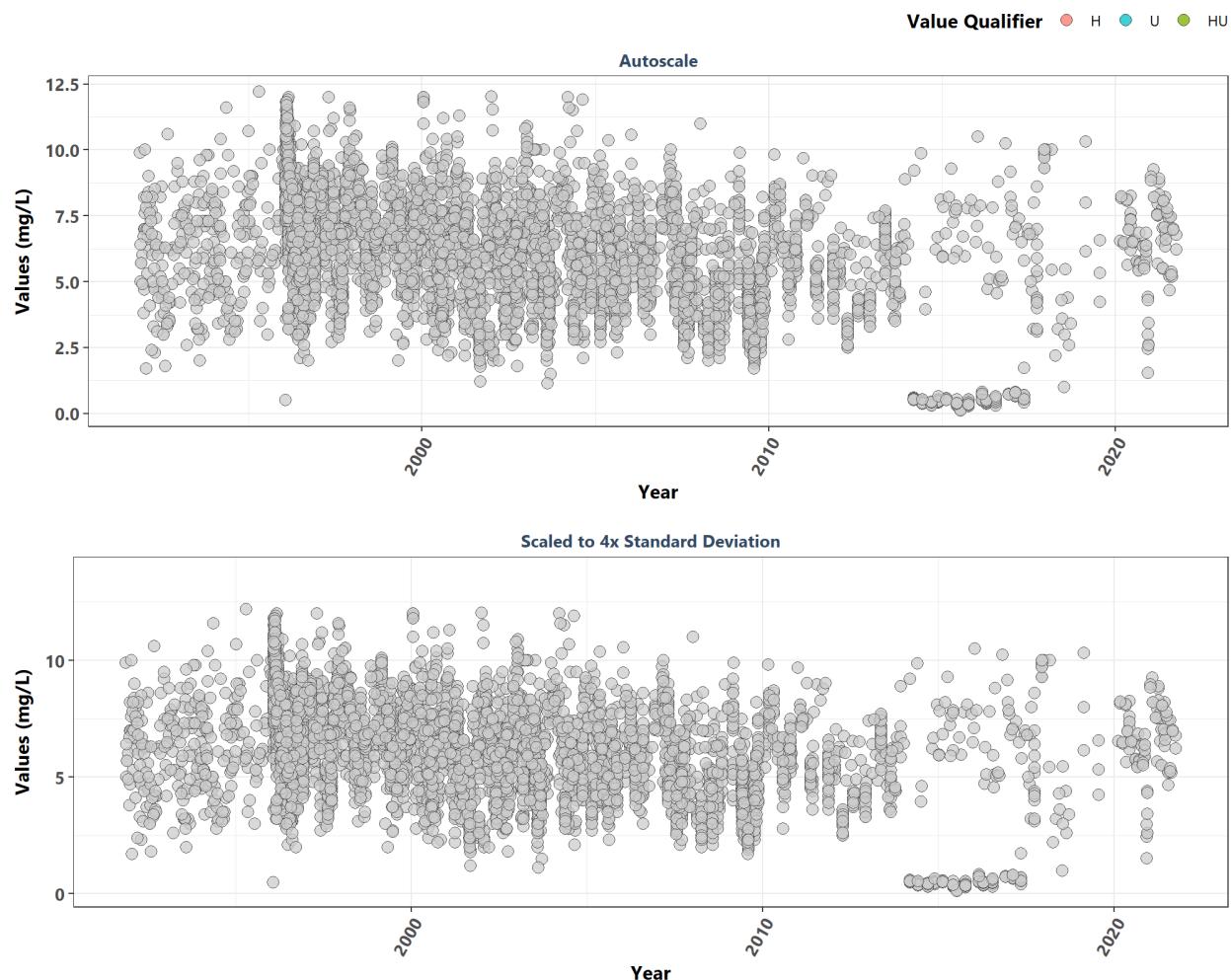
Apalachicola National Estuarine Research Reserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
16530	7.2	-0.1466	-0.05	120.9244	0	-1

^a p < 0.00005 appear as 0 due to rounding

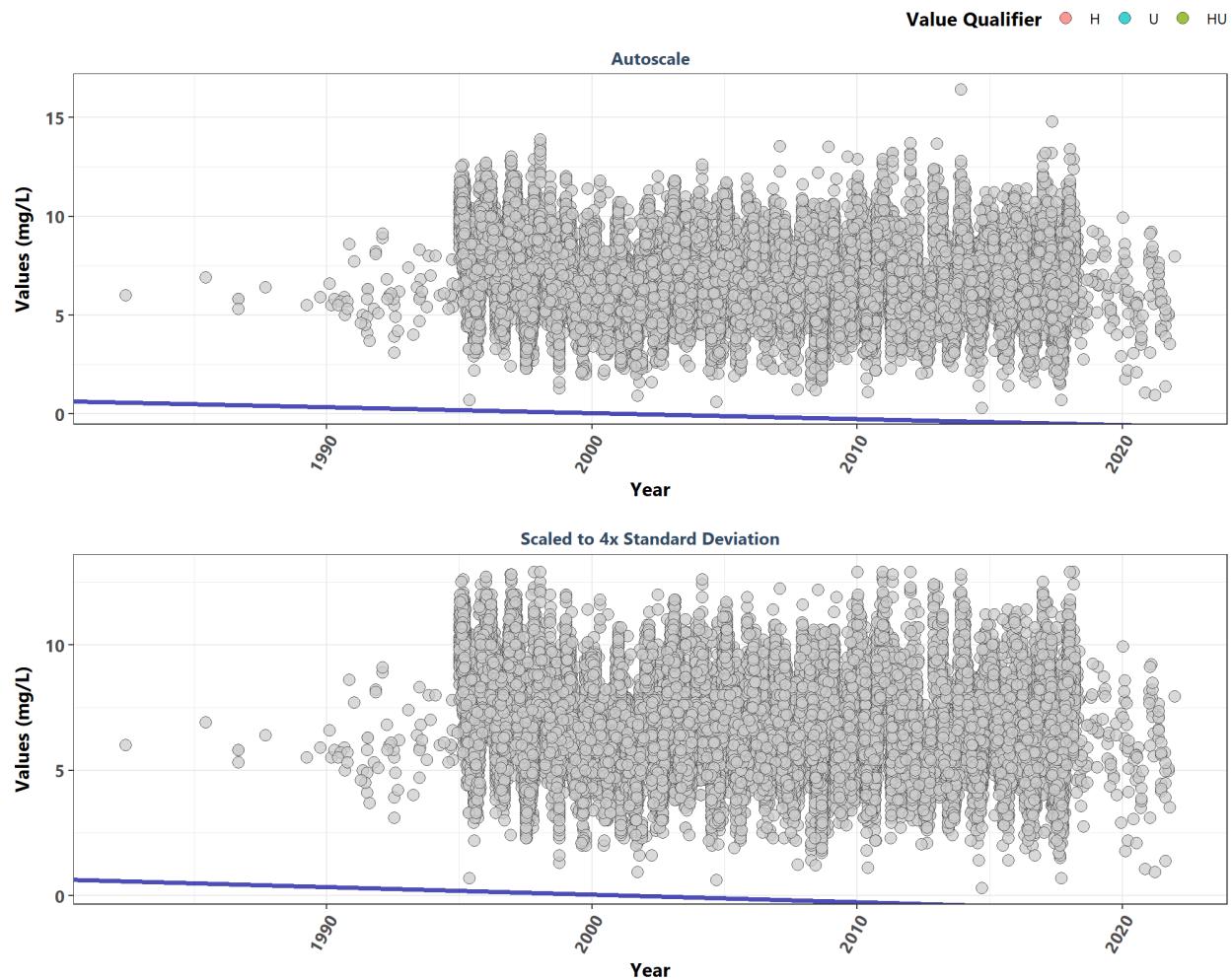
Banana River Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
5819	6.1	-0.2145	-0.1085714	258.1022	0	-1

^a p < 0.00005 appear as 0 due to rounding

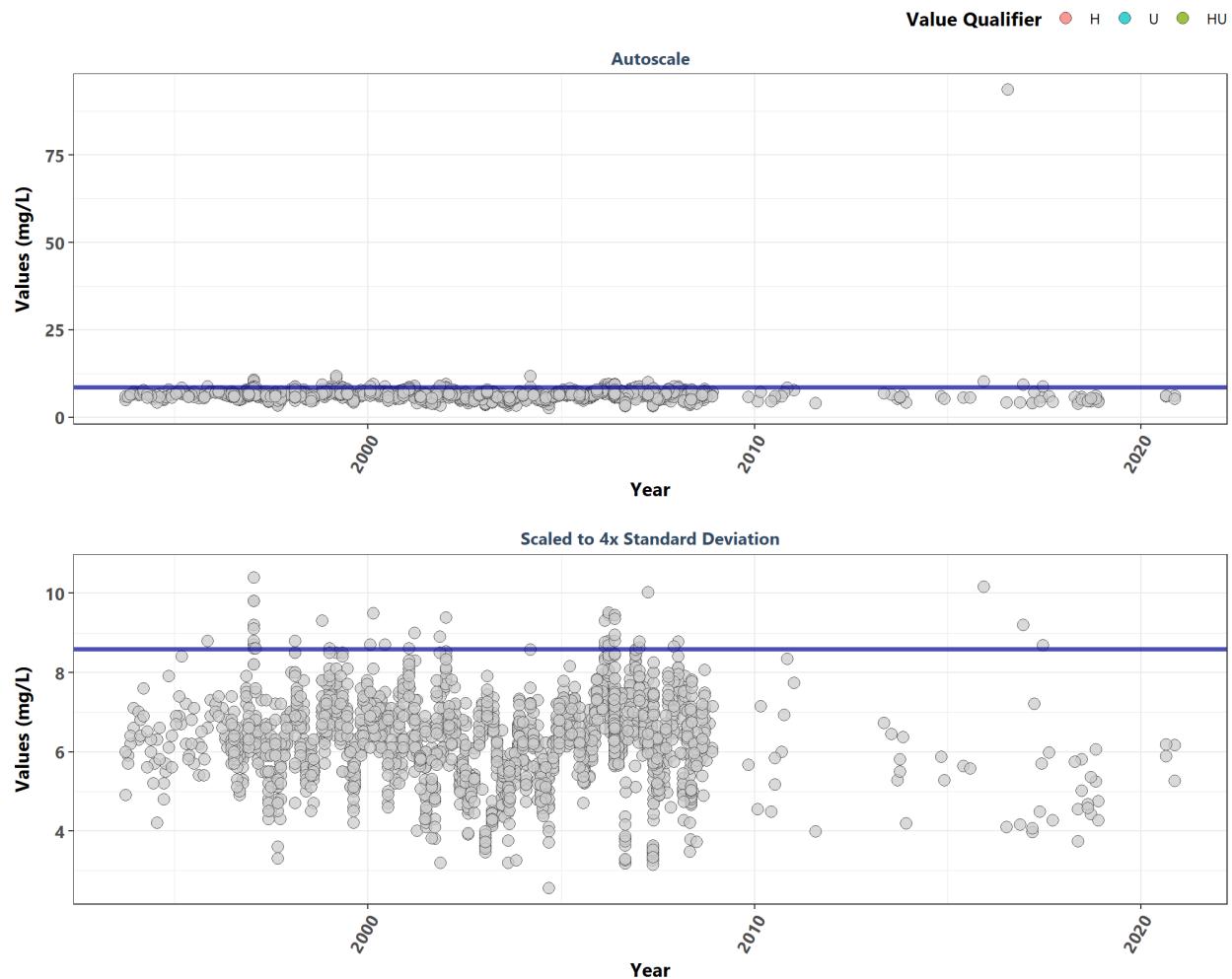
Big Bend Seagrasses Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
33163	6.6	-0.1013	-0.03	60.04	0	-1

^a p < 0.00005 appear as 0 due to rounding

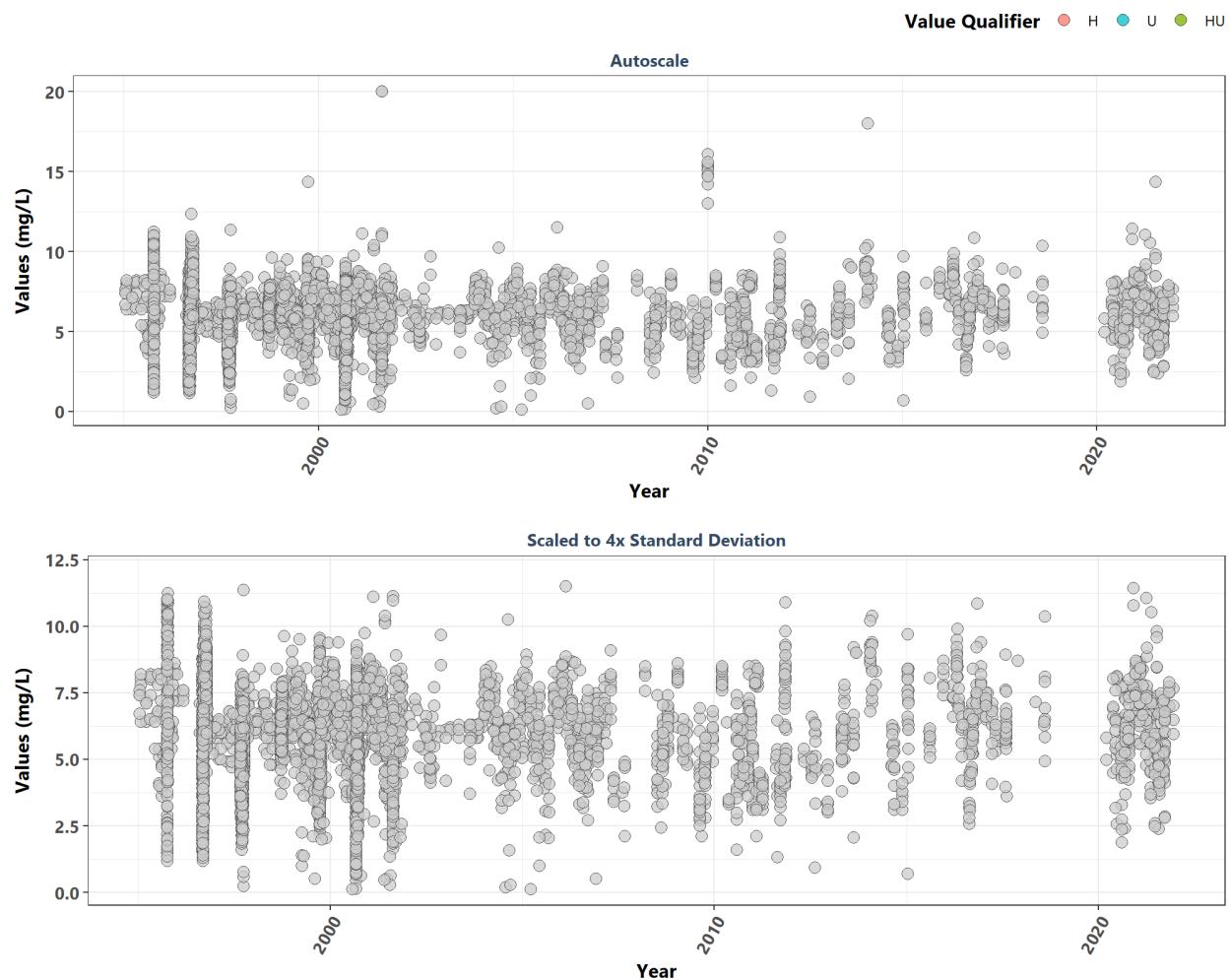
Biscayne Bay Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
1888	6.31	0.0082	0	8.588333	0.7573	0

^a p < 0.00005 appear as 0 due to rounding

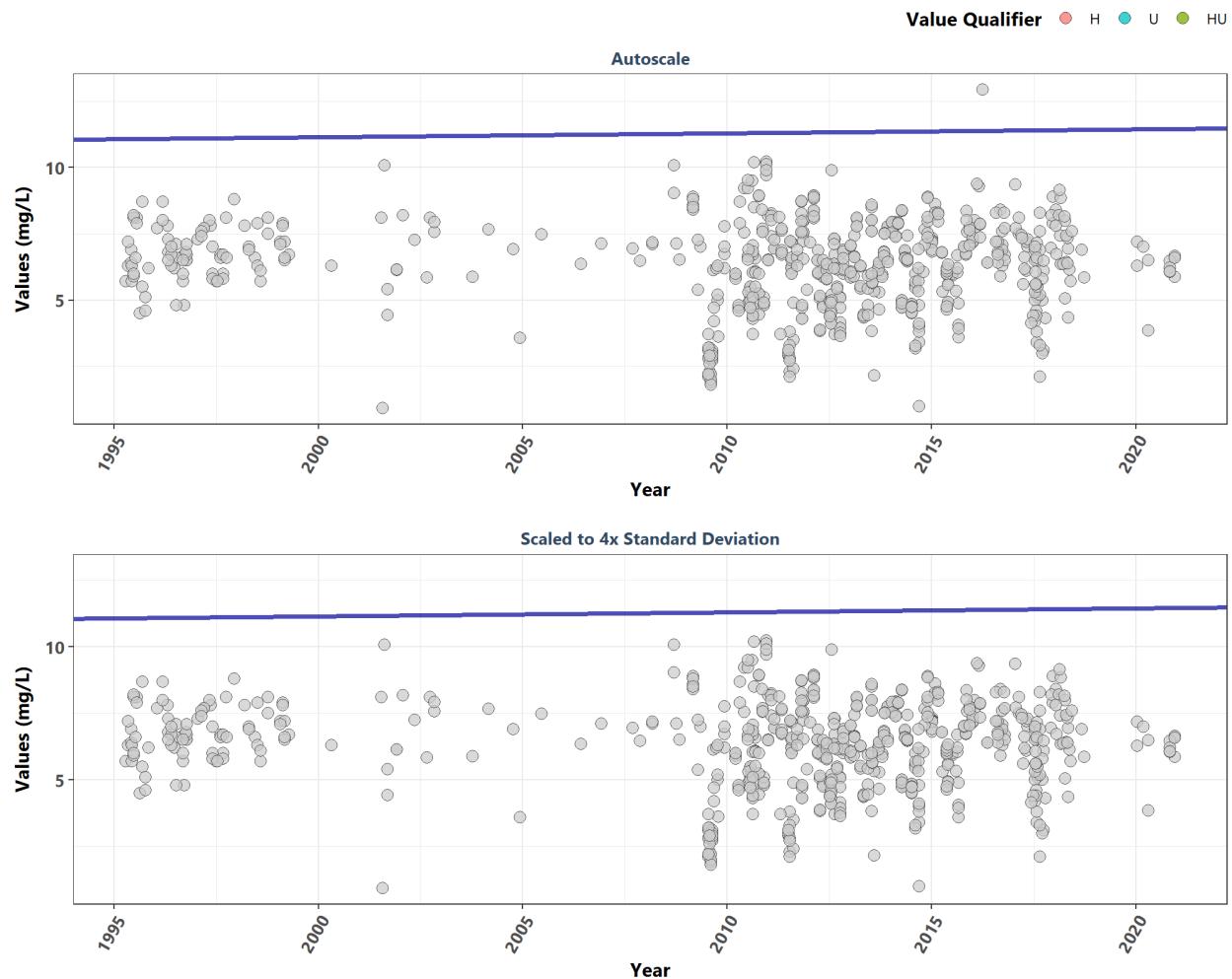
Boca Ciega Bay Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
6288	5.76	-0.0459	-0.0275	11.79603	0.0002	-1

^a p < 0.00005 appear as 0 due to rounding

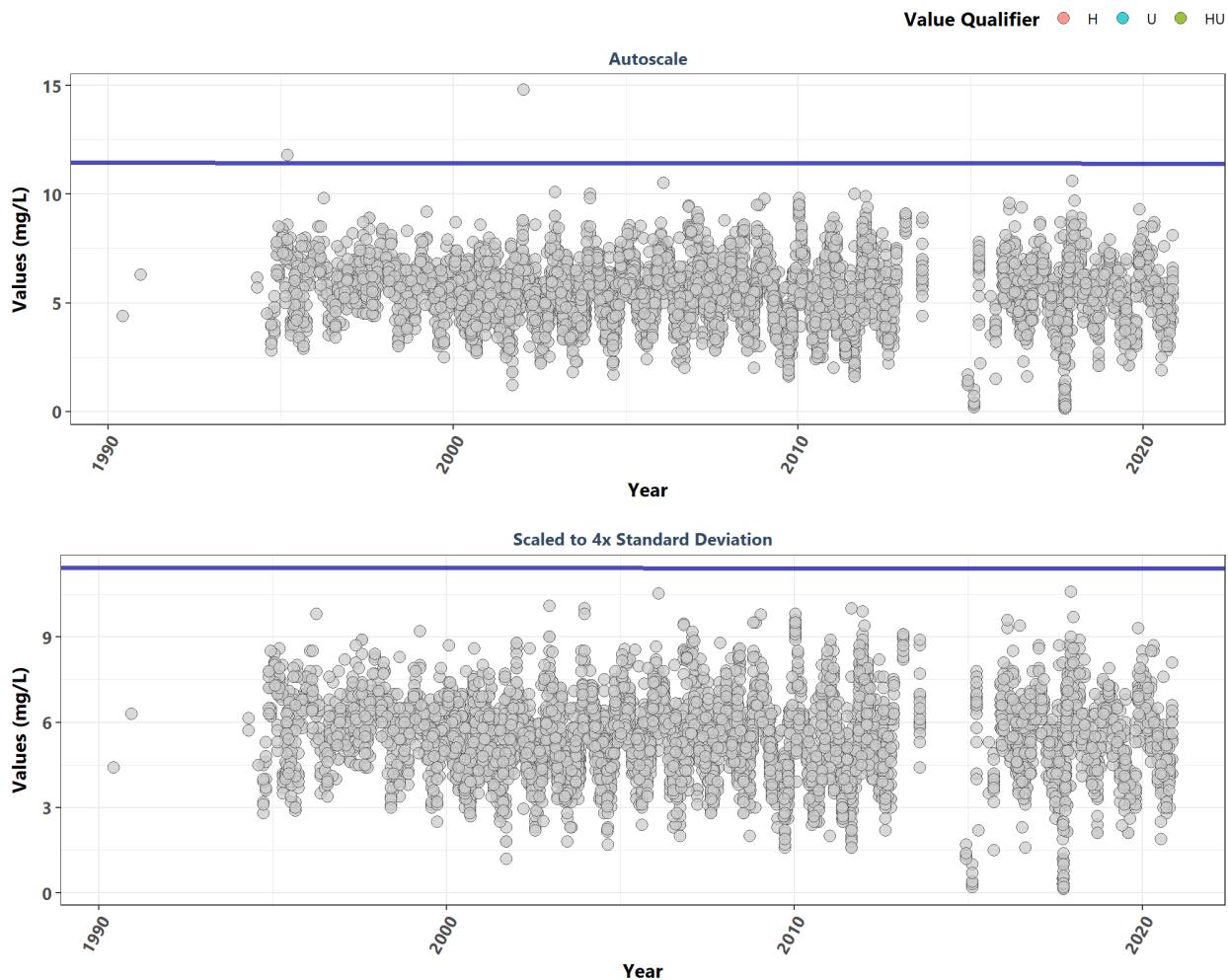
Cape Haze Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
654	6.49	0.0228	0.015	-18.85811	0.1321	0

^a p < 0.00005 appear as 0 due to rounding

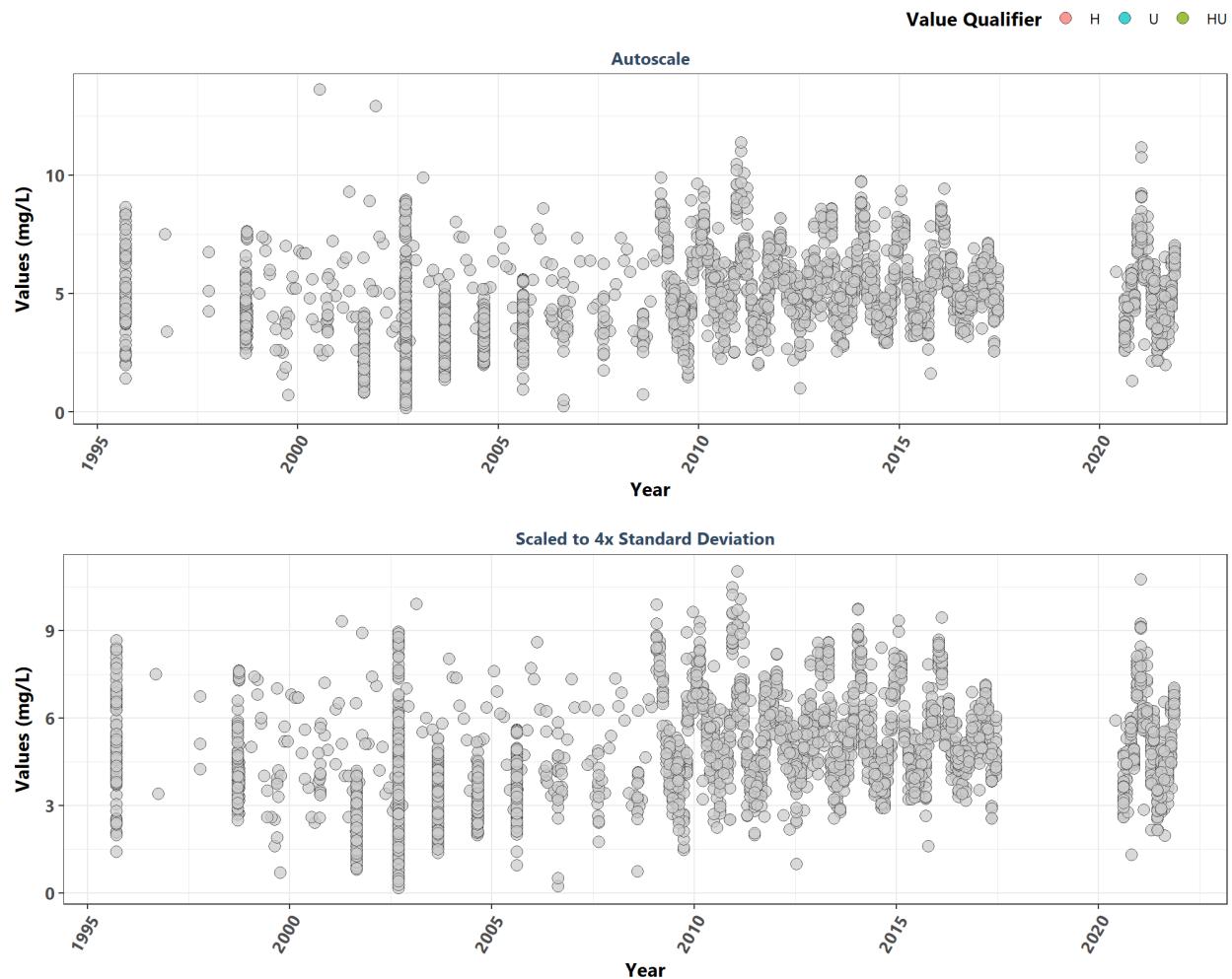
Cape Romano-Ten Thousand Islands Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
4773	5.5	-0.0126	-0.00125	13.93273	0.0608	0

^a p < 0.00005 appear as 0 due to rounding

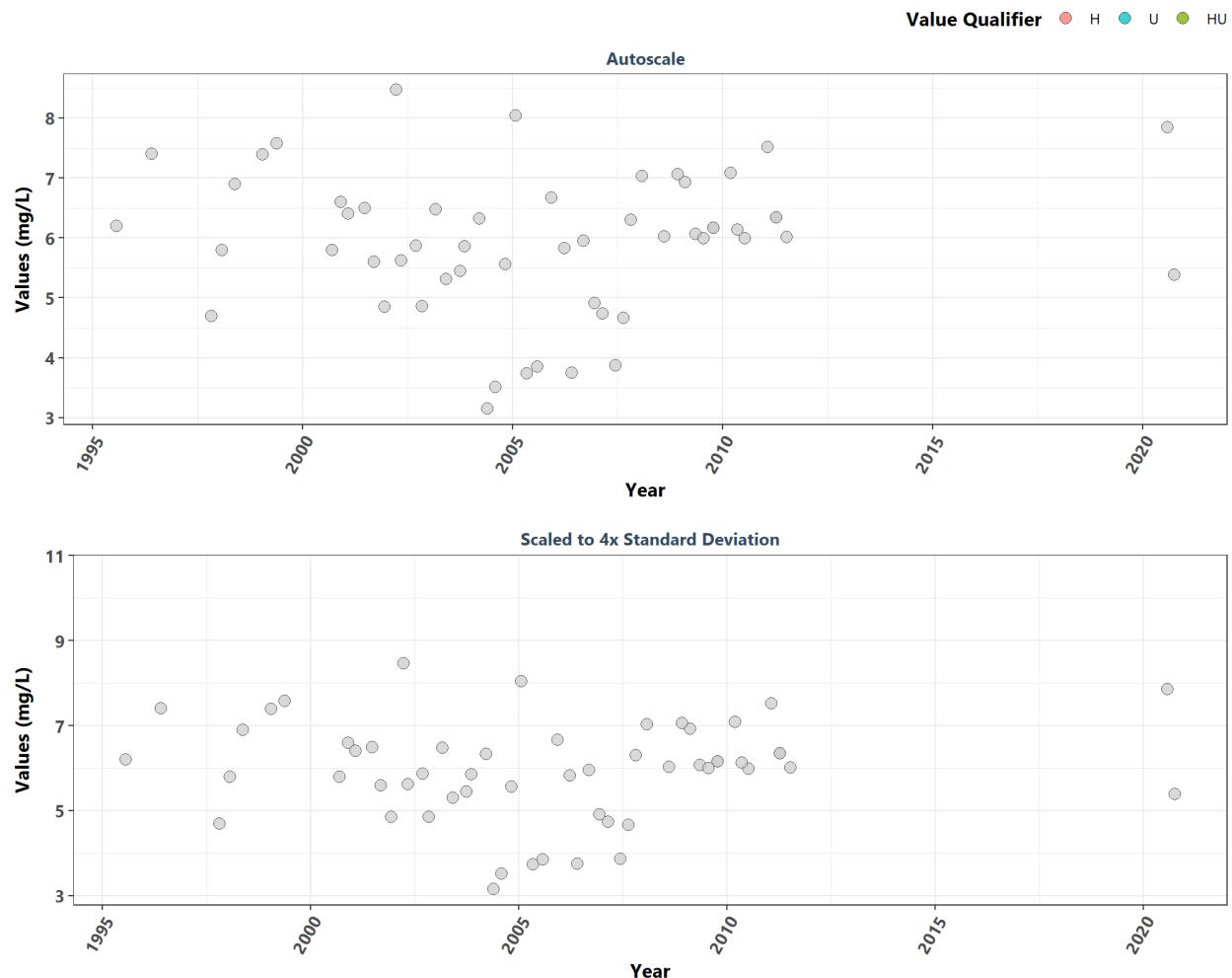
Cockroach Bay Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
3874	4.01	0.0512	0.0525	-8.650333	0	1

^a p < 0.00005 appear as 0 due to rounding

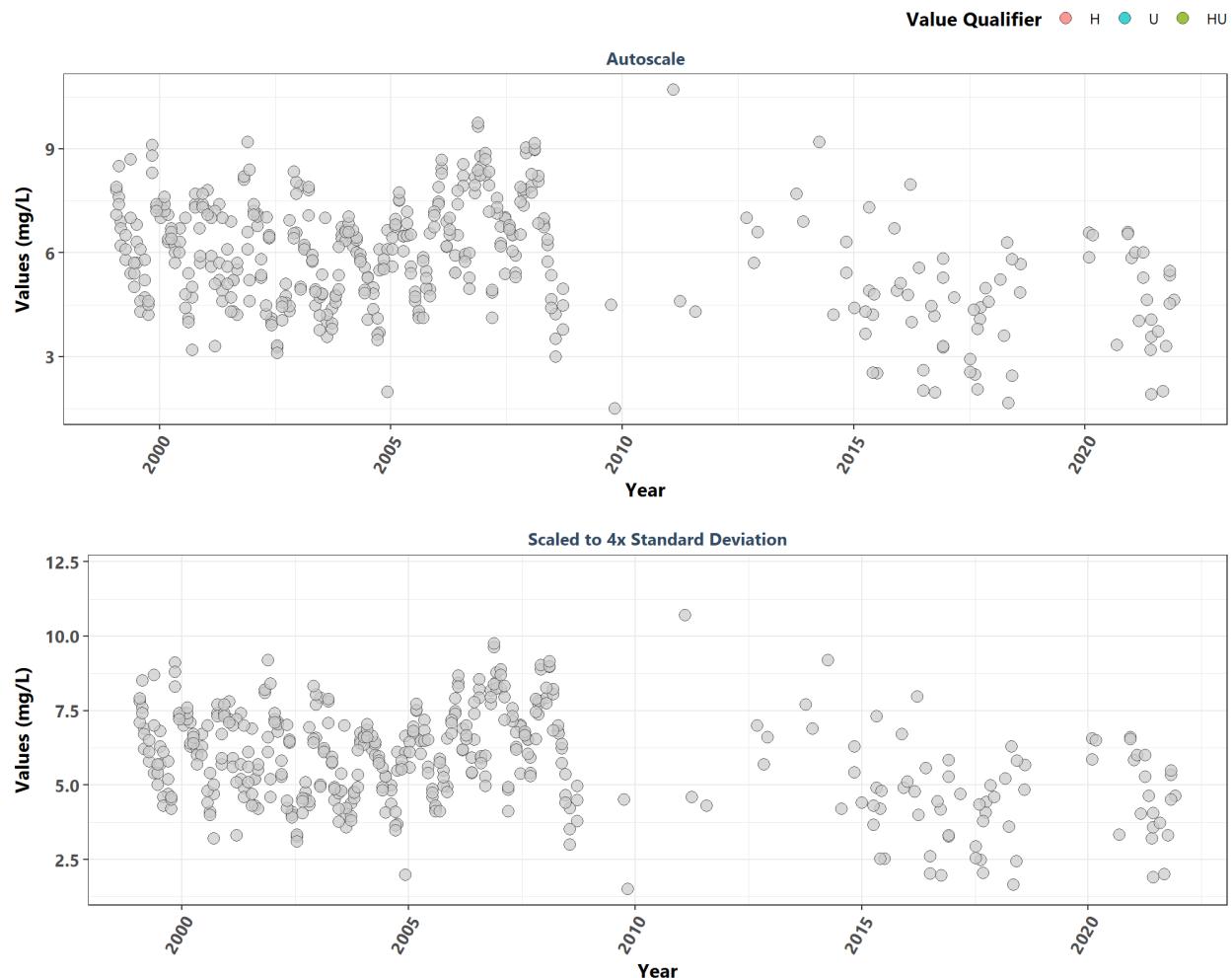
Coupon Eight Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
54	6.0178	0.15	0.0278992	-55.00893	0.3927	0

^a p < 0.00005 appear as 0 due to rounding

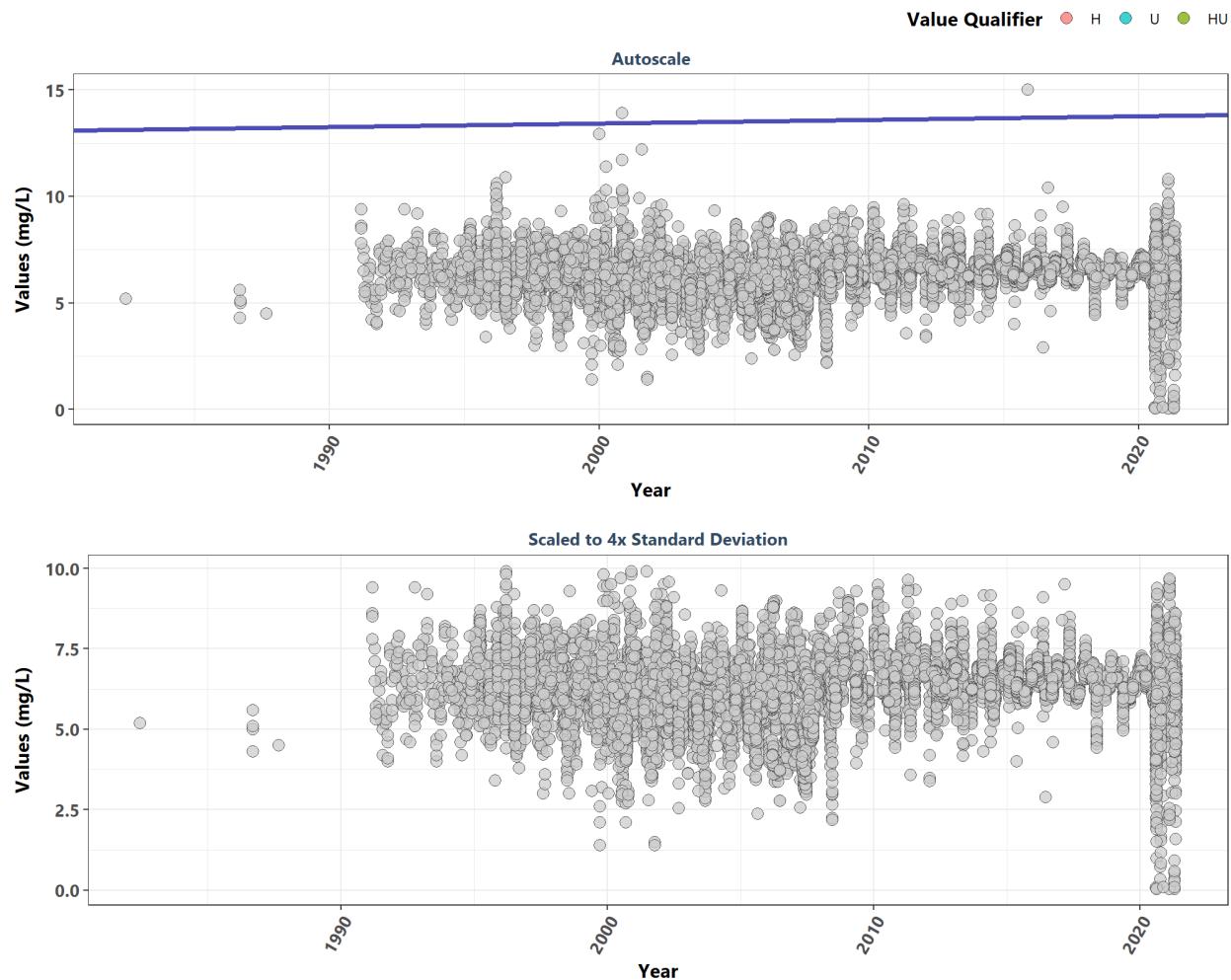
Estero Bay Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
412	5.975	-0.0903	-0.0351471	68.32358	0.0056	-1

^a p < 0.00005 appear as 0 due to rounding

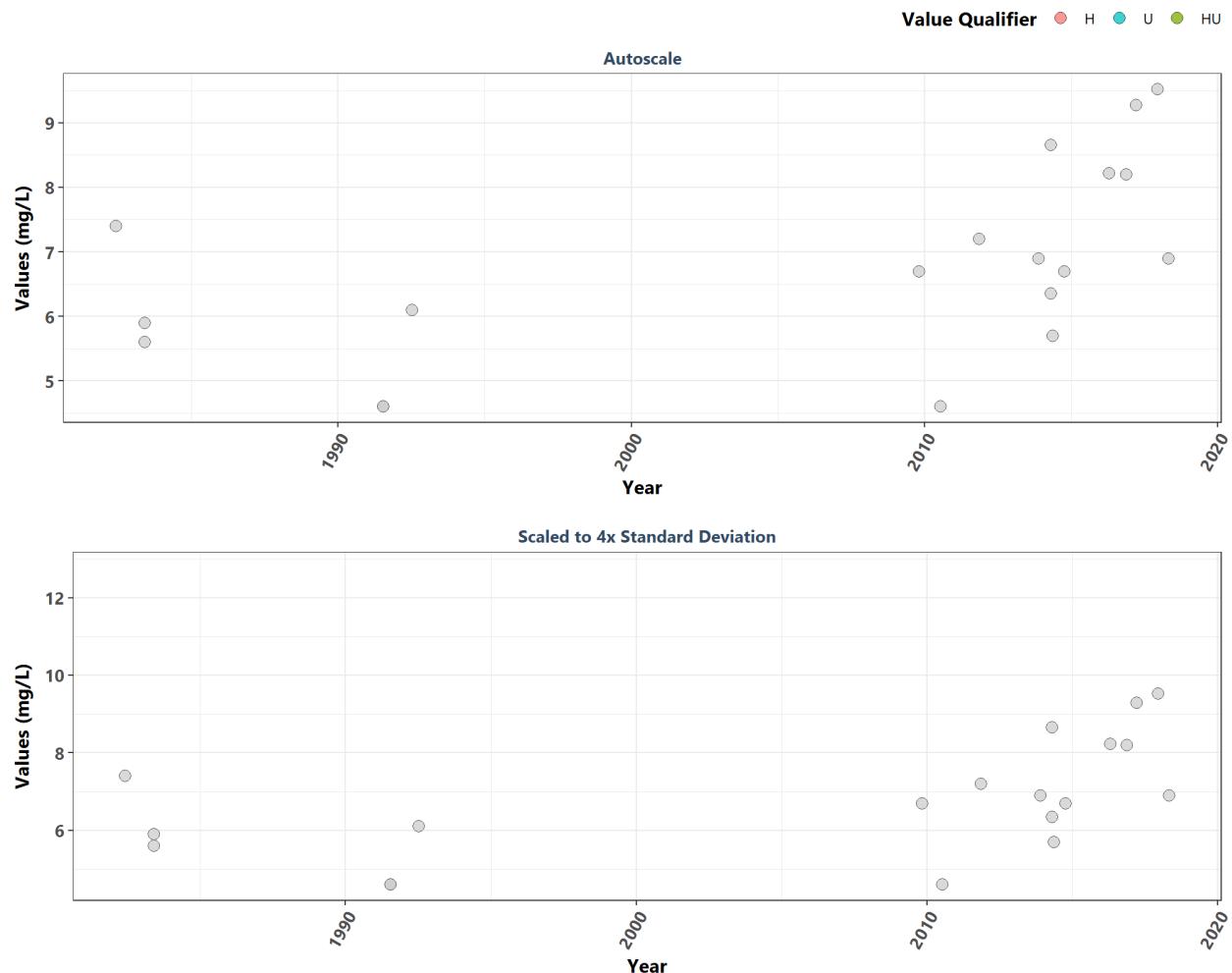
Florida Keys National Marine Sanctuary



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
16347	6.27817	0.1311	0.0168421	-20.26168	0	1

^a p < 0.00005 appear as 0 due to rounding

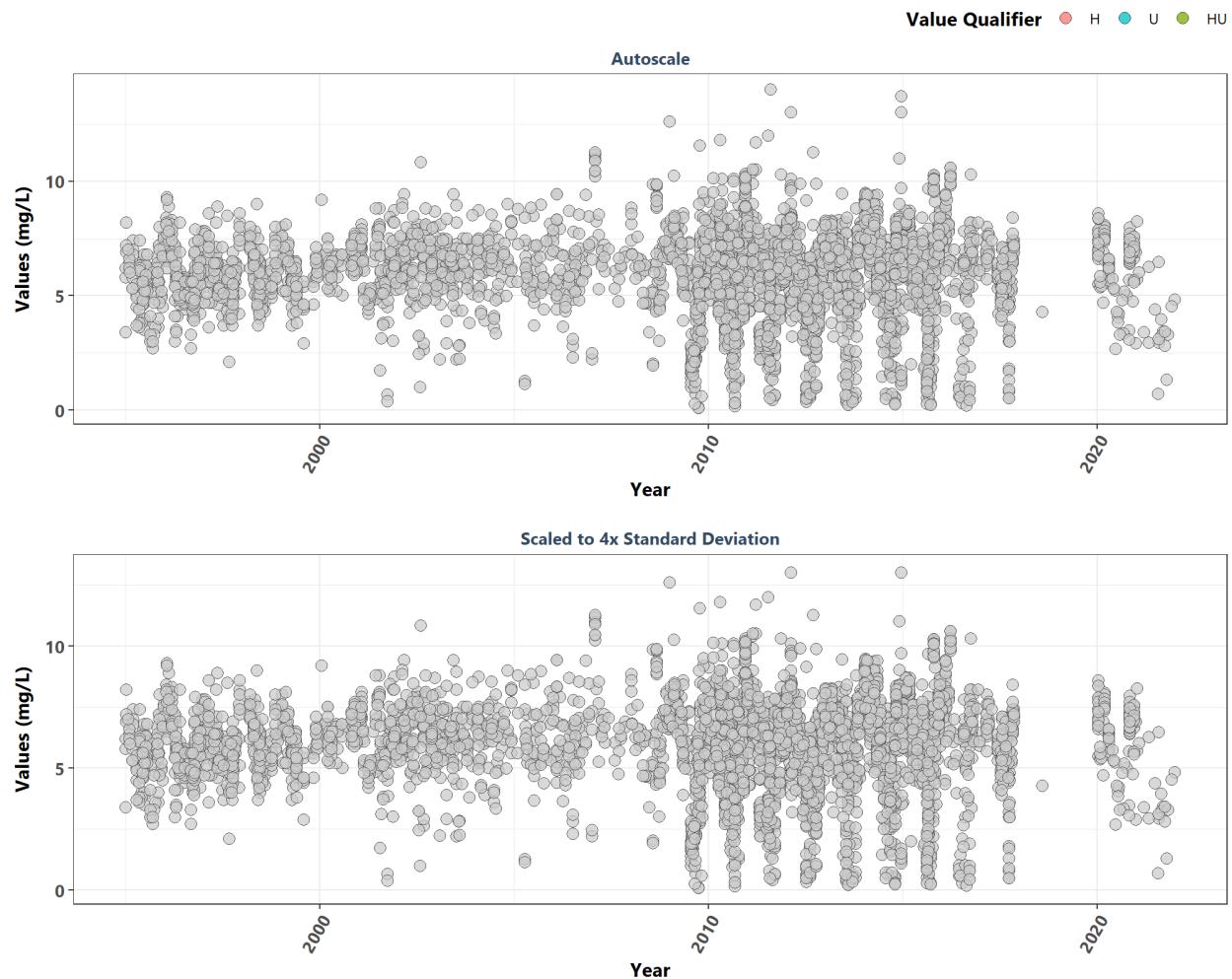
Fort Pickens State Park Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
19	6.7	0.098	0	-195.4	1	0

^a p < 0.00005 appear as 0 due to rounding

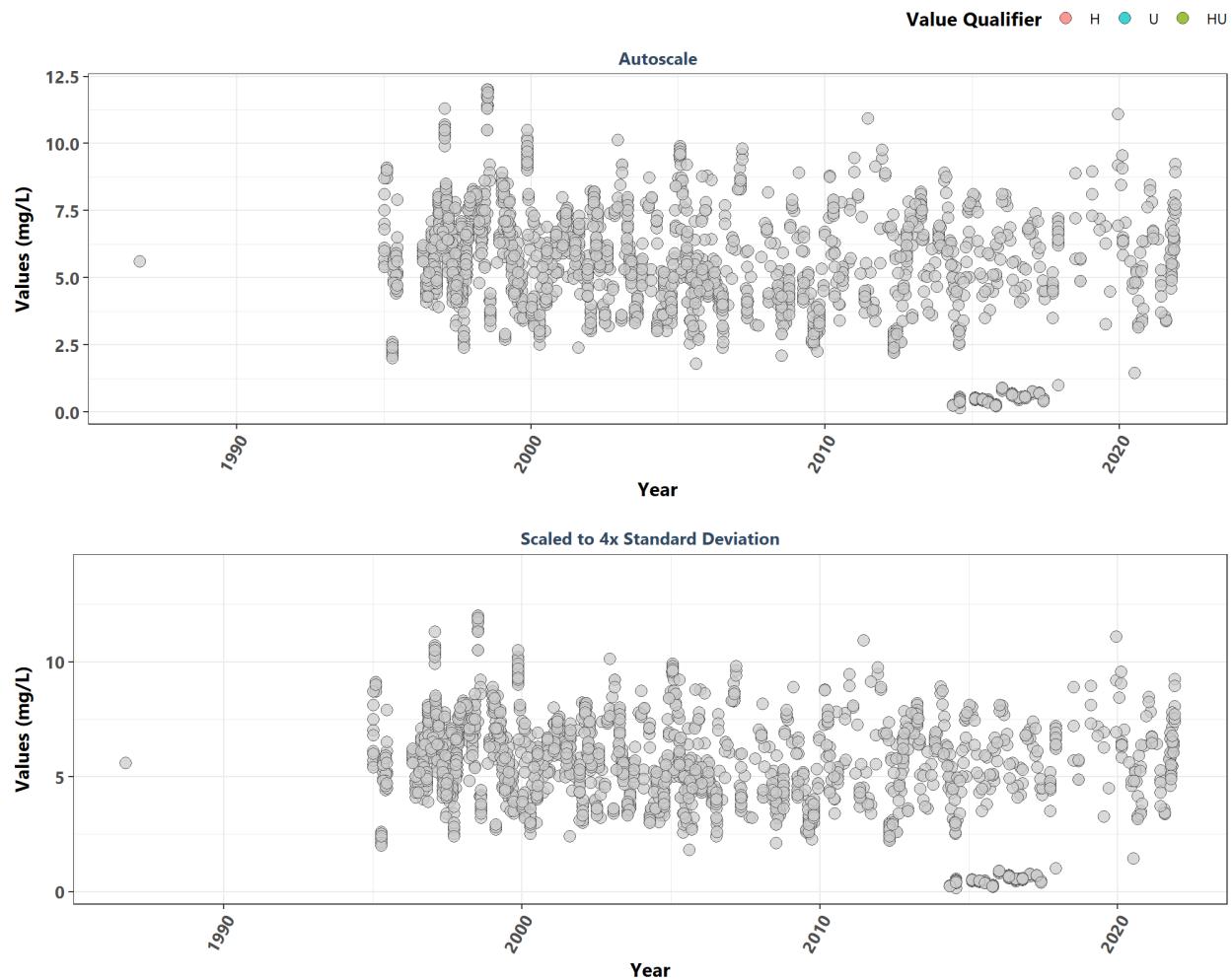
Gasparilla Sound-Charlotte Harbor Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
4520	6.21	0.0617	0.0166667	-36.7581	0	1

^a p < 0.00005 appear as 0 due to rounding

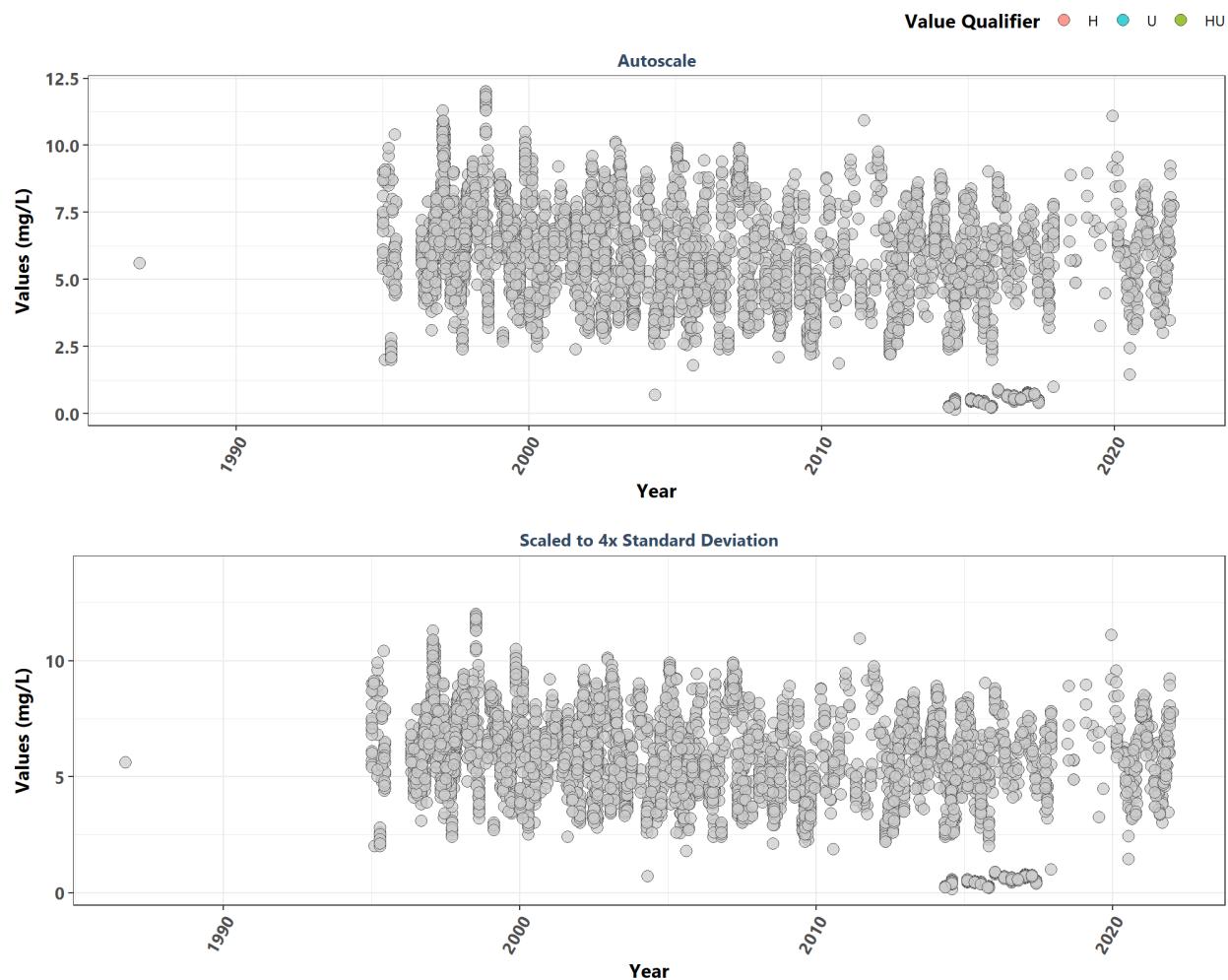
Guana River Marsh Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
2168	5.5	-0.2312	-0.1	129.9518	0	-1

^a p < 0.00005 appear as 0 due to rounding

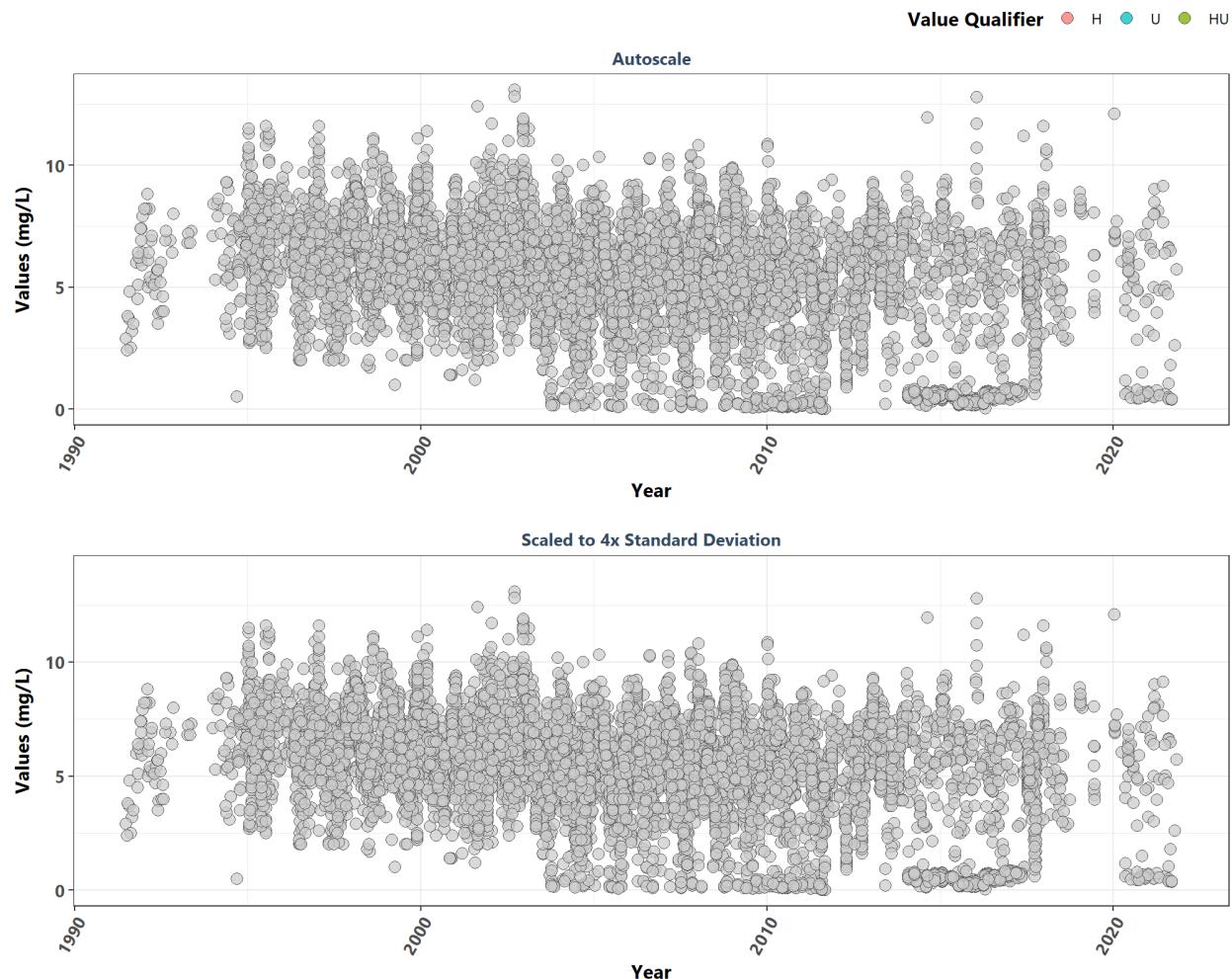
Guana Tolomato Matanzas National Estuarine Research Reserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
5504	5.8	-0.2301	-0.0888889	159.8853	0	-1

^a p < 0.00005 appear as 0 due to rounding

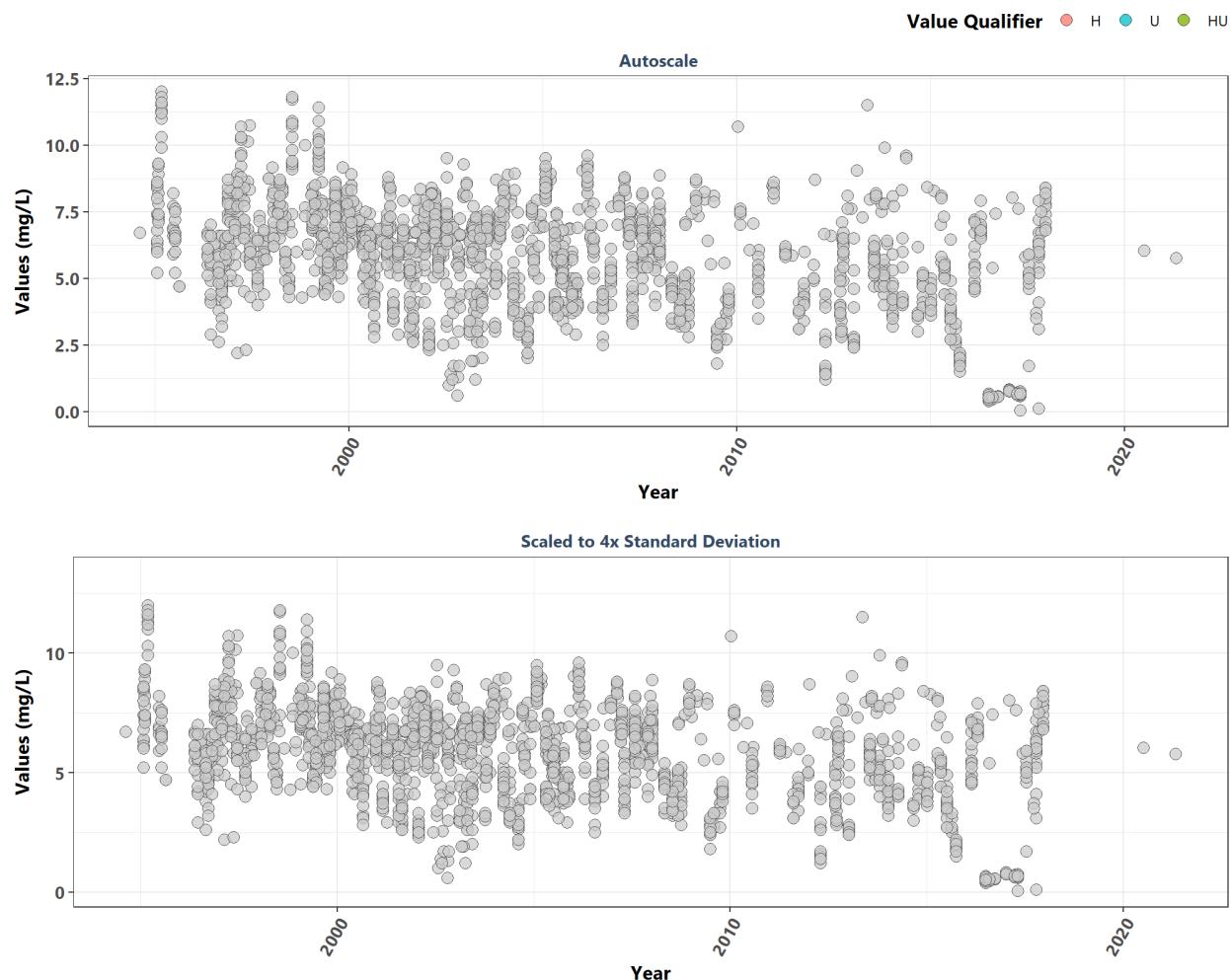
Indian River-Malabar to Vero Beach Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
9814	5.6	-0.2429	-0.1125	215.5022	0	-1

^a p < 0.00005 appear as 0 due to rounding

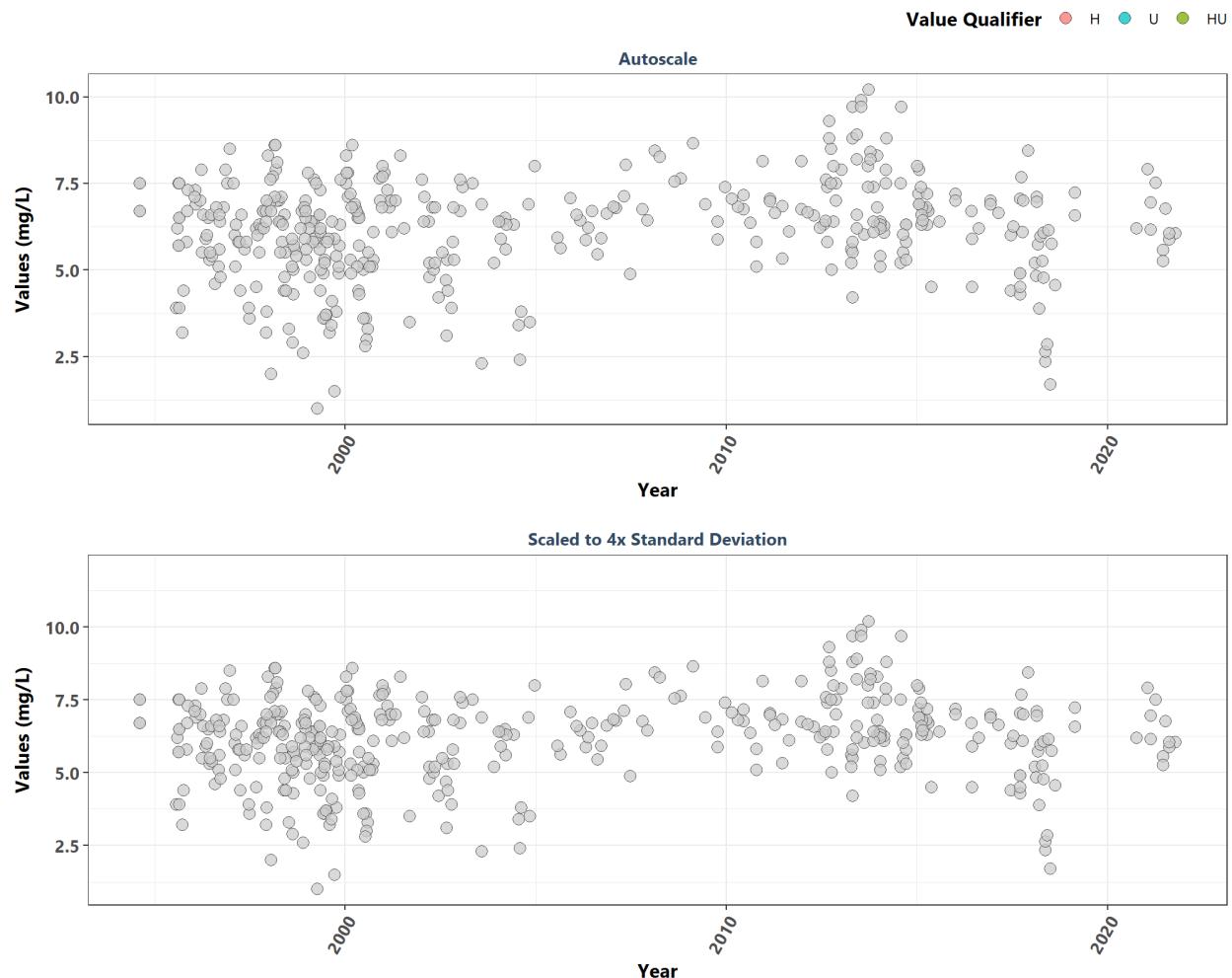
Indian River-Vero Beach to Ft. Pierce Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
2001	6	-0.2425	-0.12	214.9297	0	-1

^a p < 0.00005 appear as 0 due to rounding

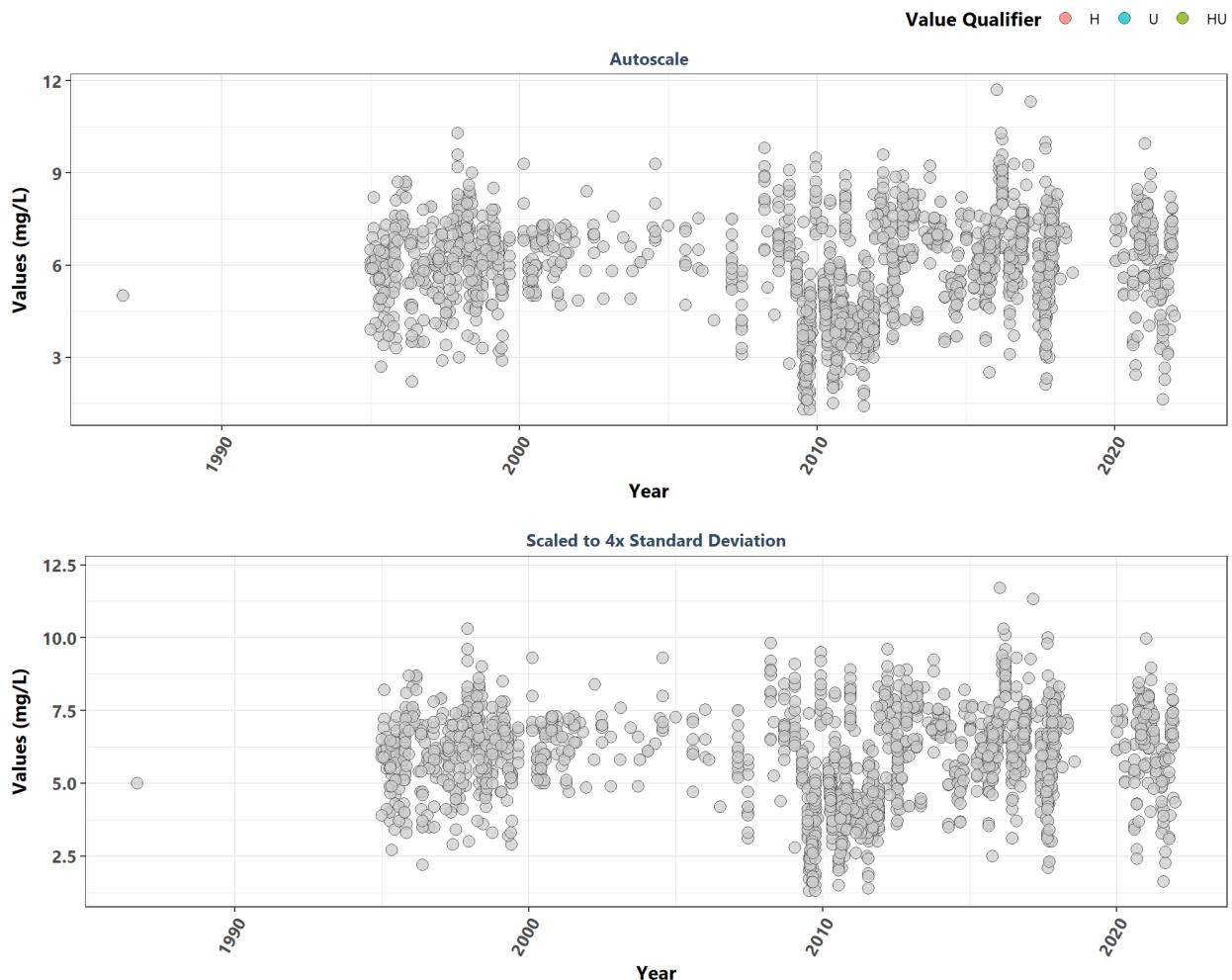
Jensen Beach to Jupiter Inlet Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
415	6.3	0.0491	0.0066667	-28.76357	0.2797	0

^a p < 0.00005 appear as 0 due to rounding

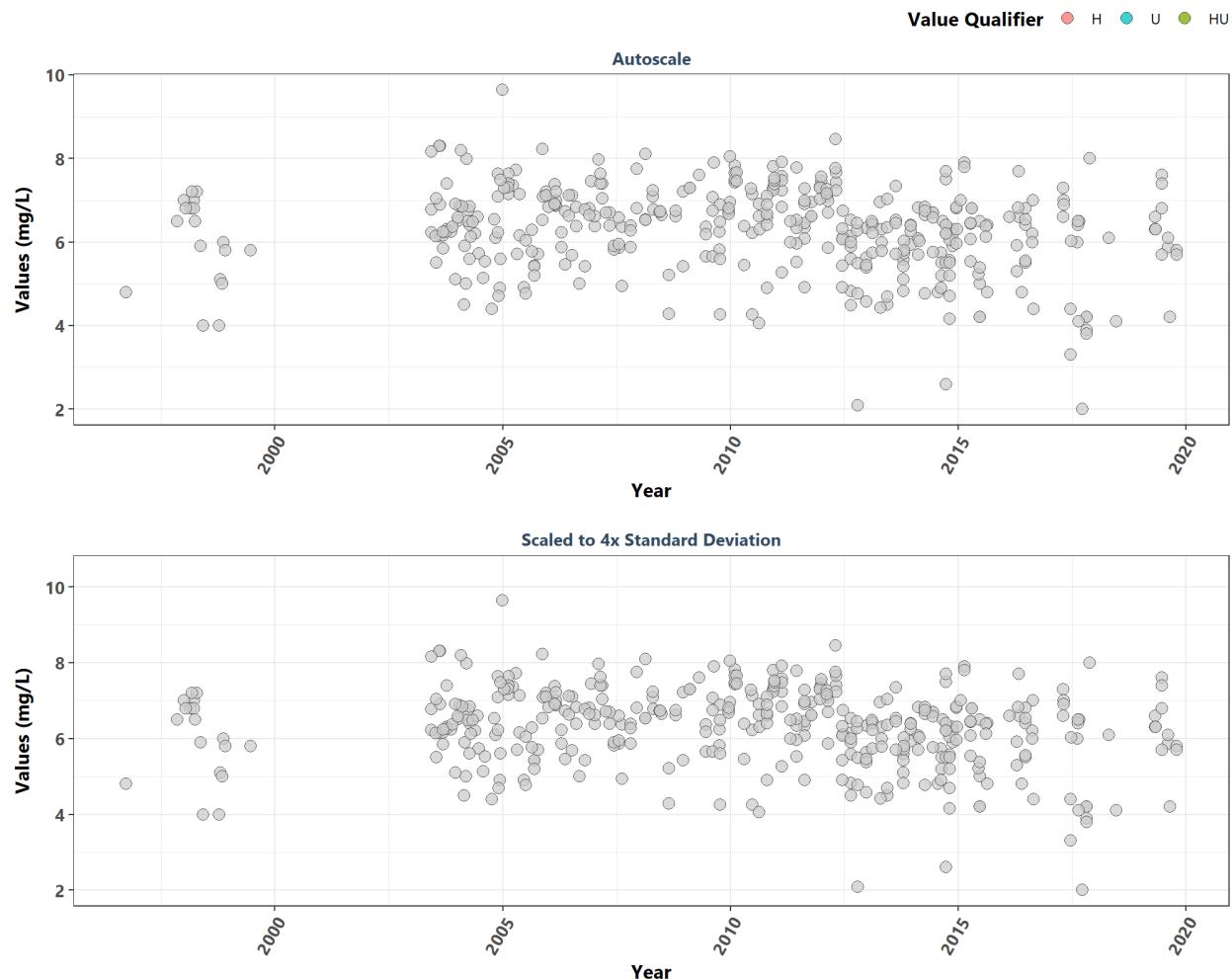
Lemon Bay Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
1842	5.9	0.0545	0.015	-11.97967	0.0017	1

^a p < 0.00005 appear as 0 due to rounding

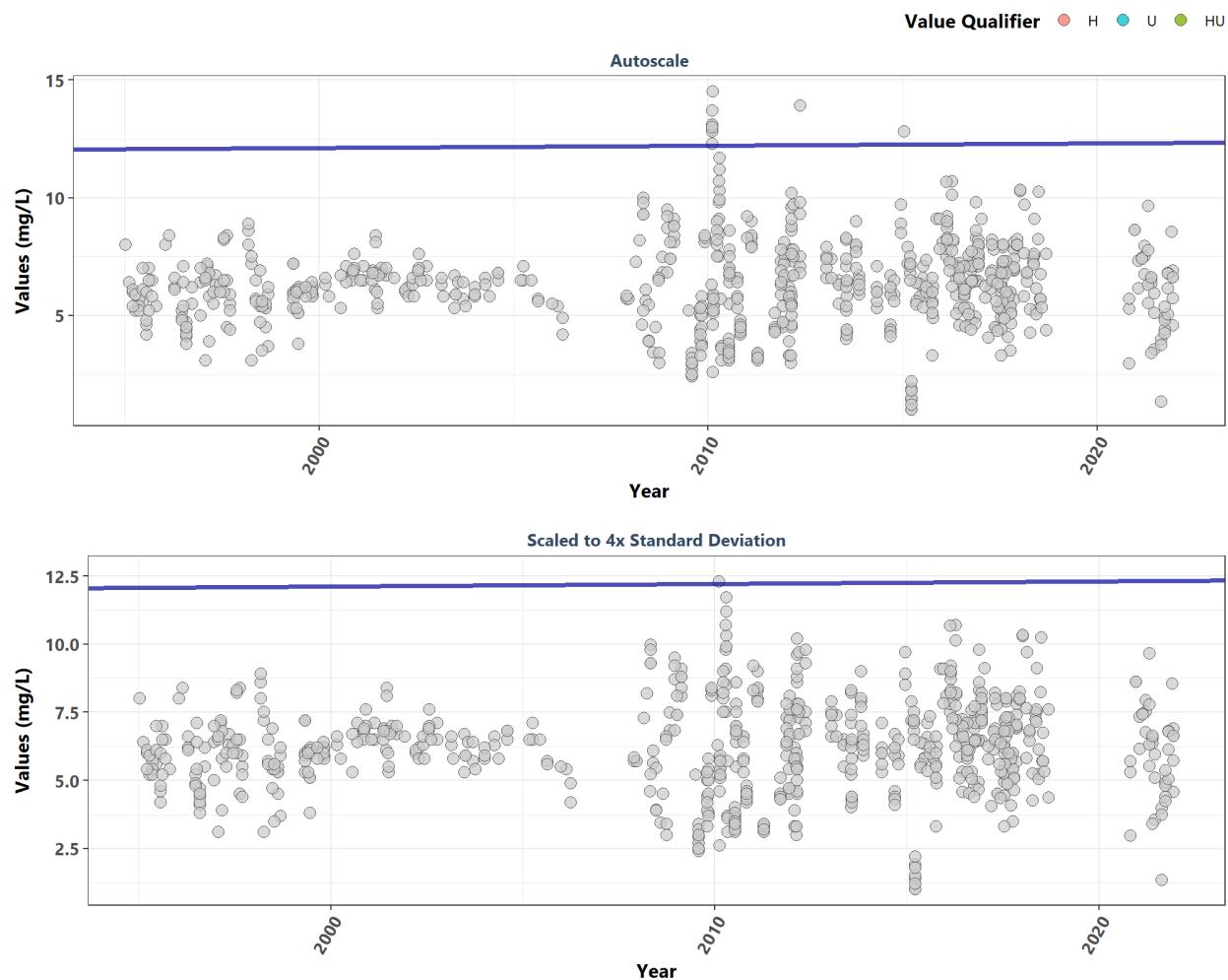
Loxahatchee River-Lake Worth Creek Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
401	6.4	-0.1071	-0.0433333	70.2825	0.0002	-1

^a p < 0.00005 appear as 0 due to rounding

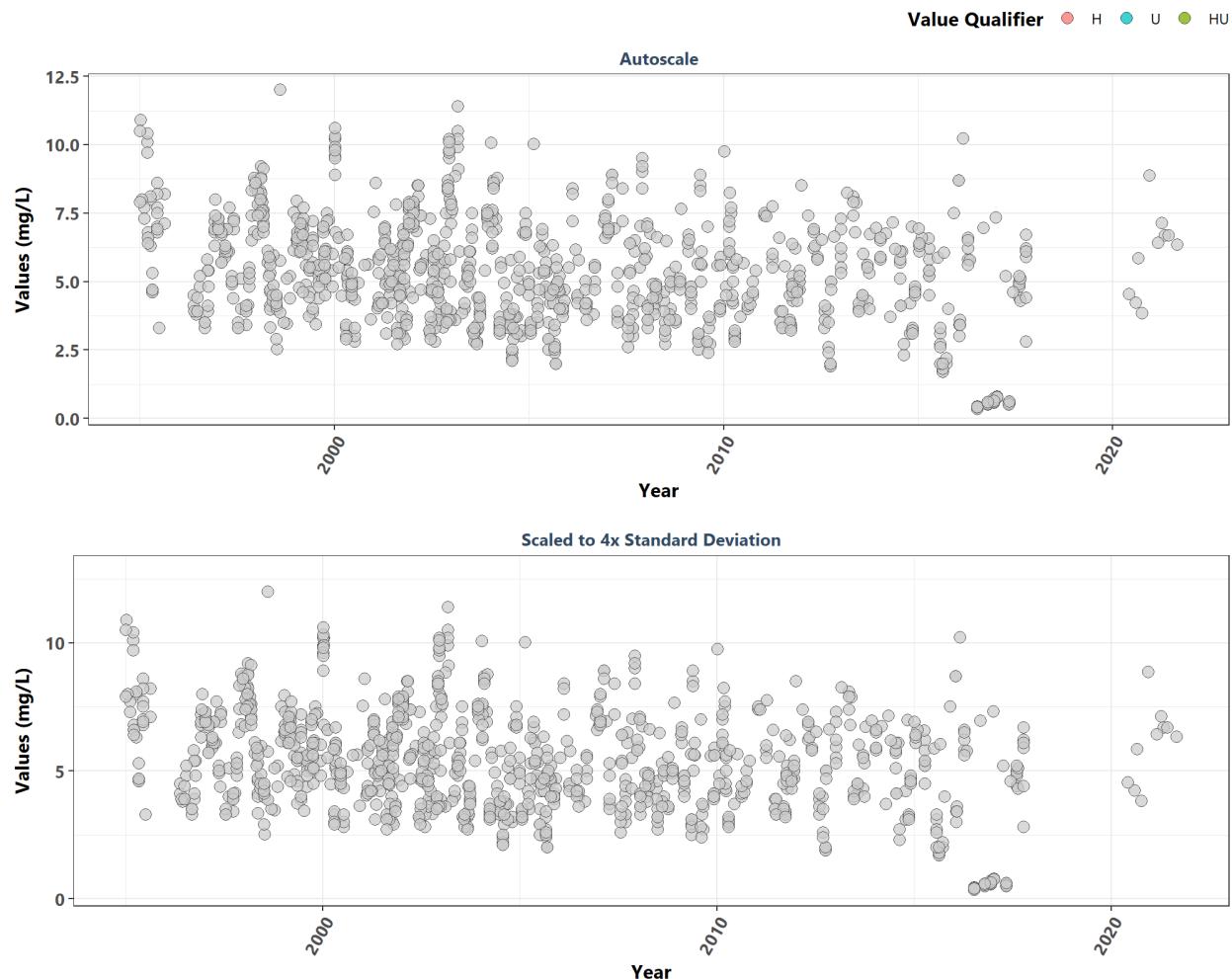
Matlacha Pass Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
720	6.24	0.0398	0.0094868	-6.855921	0.2334	0

^a p < 0.00005 appear as 0 due to rounding

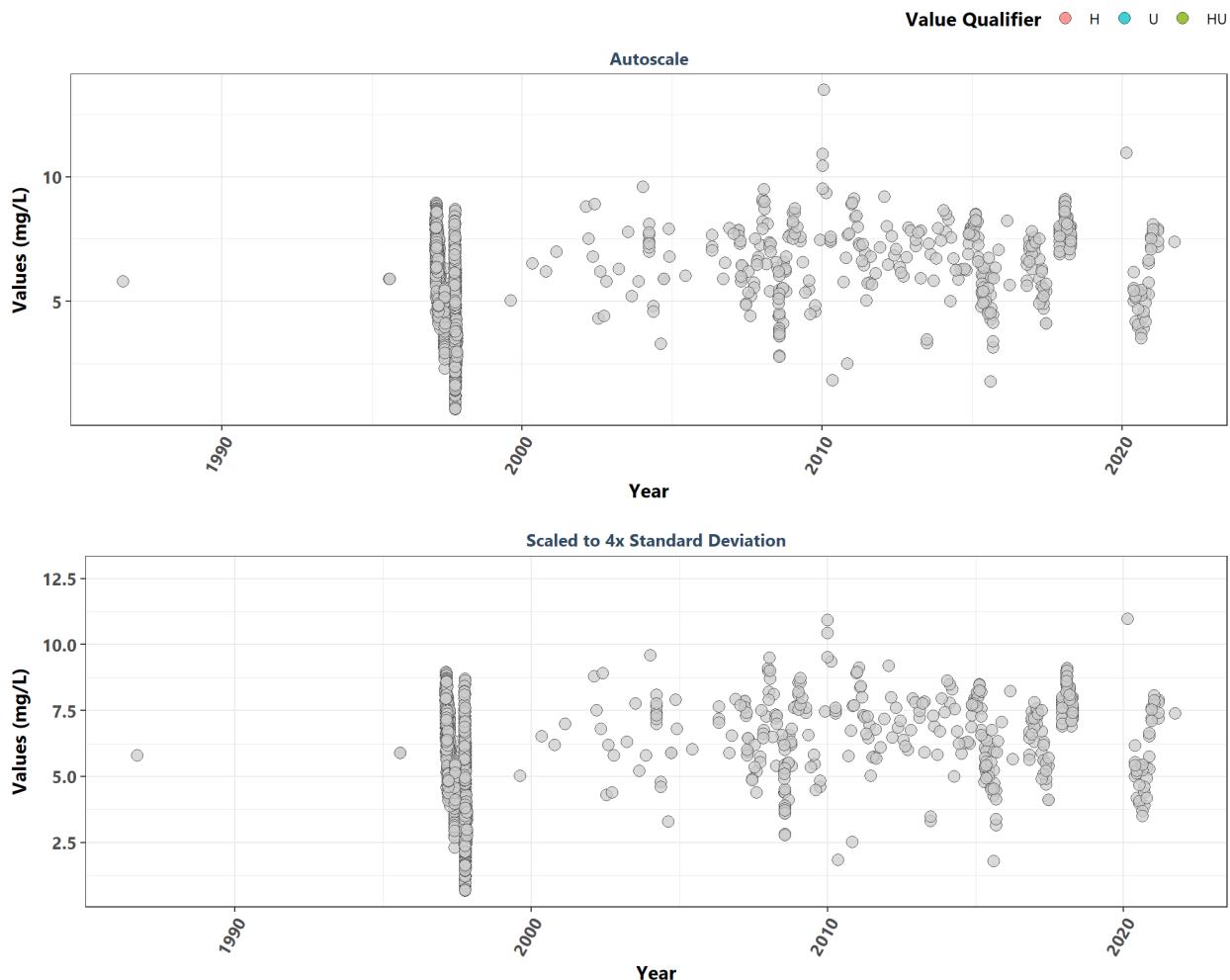
Mosquito Lagoon Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
1093	5.2	-0.1676	-0.08	137.8167	0	-1

^a p < 0.00005 appear as 0 due to rounding

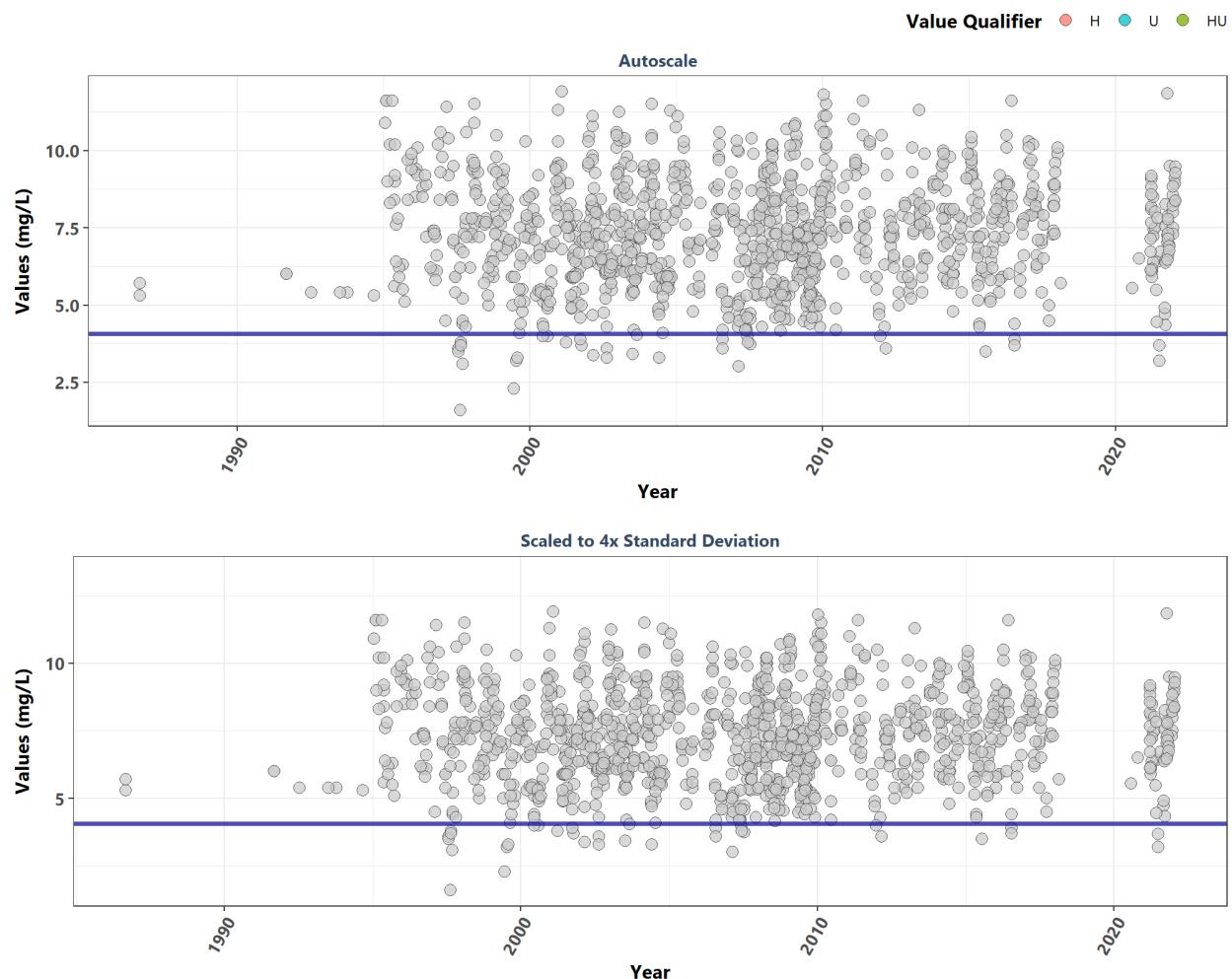
Nassau River-St. Johns River Marshes Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
2015	5.64	0.0867	0.0788235	-12.43333	0	1

^a p < 0.00005 appear as 0 due to rounding

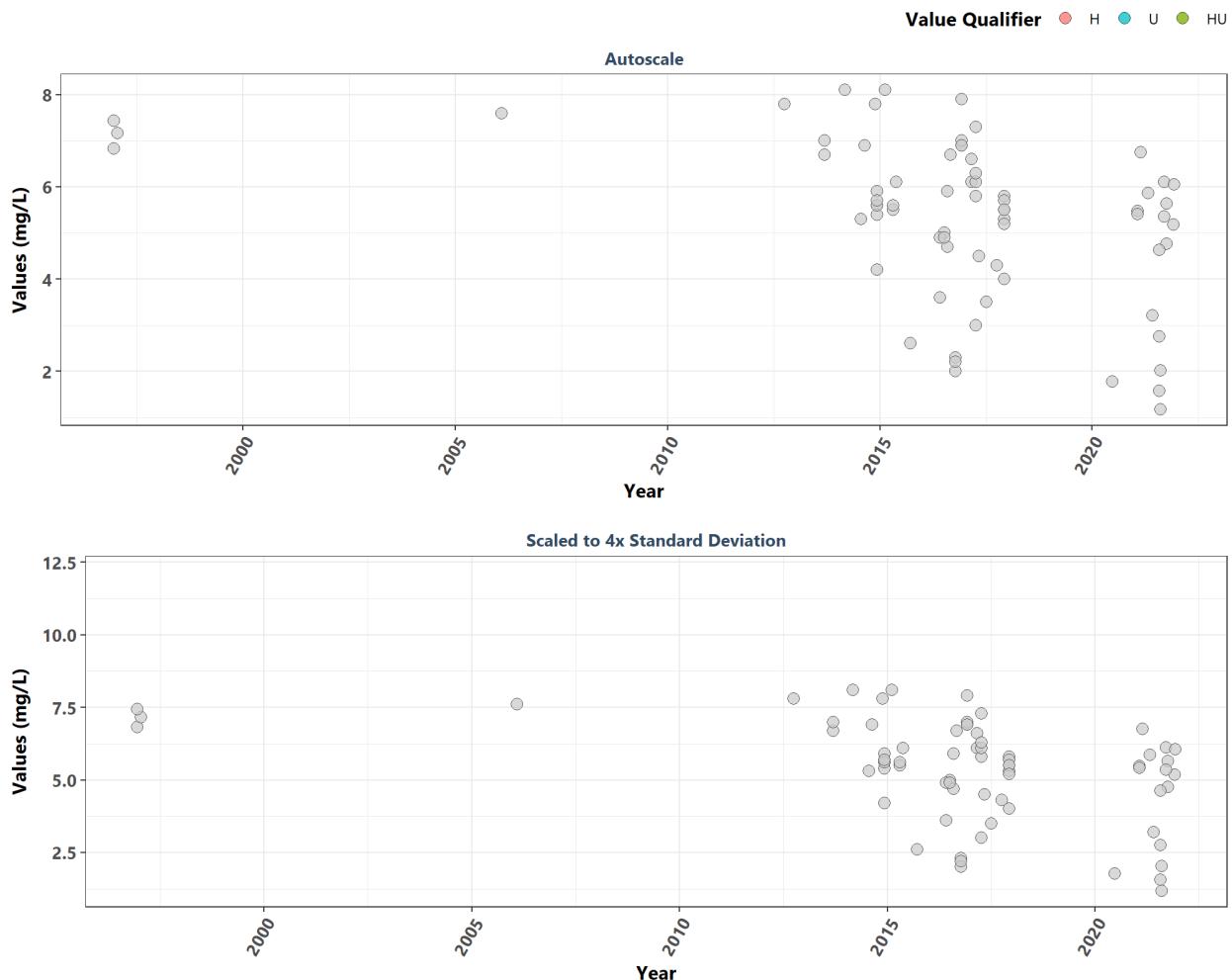
Nature Coast Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
1204	7.27	-0.0074	0	4.0775	0.7402	0

^a p < 0.00005 appear as 0 due to rounding

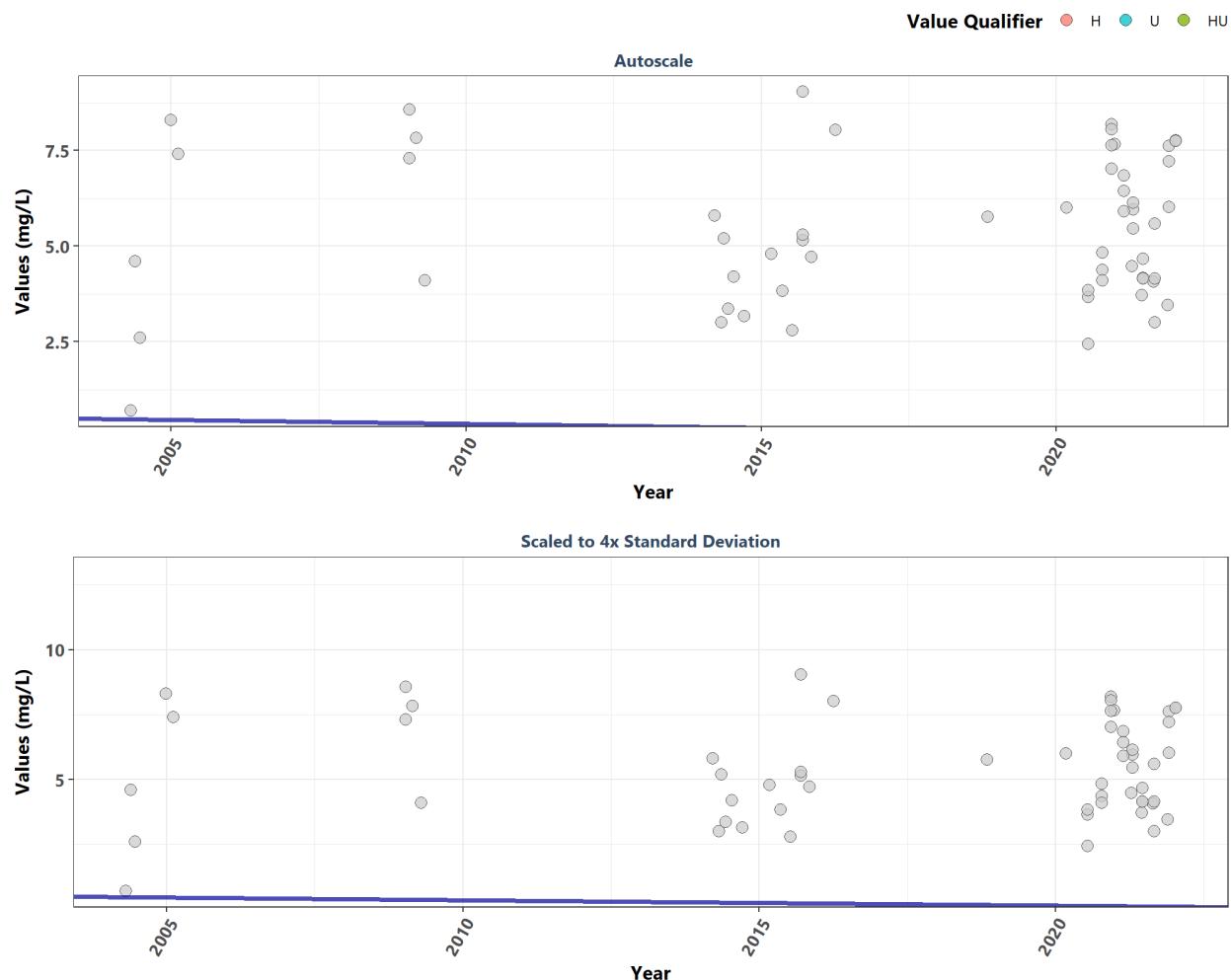
North Fork St. Lucie Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
70	5.6	-0.3106	-0.0729167	230.6294	0.0373	-1

^a p < 0.00005 appear as 0 due to rounding

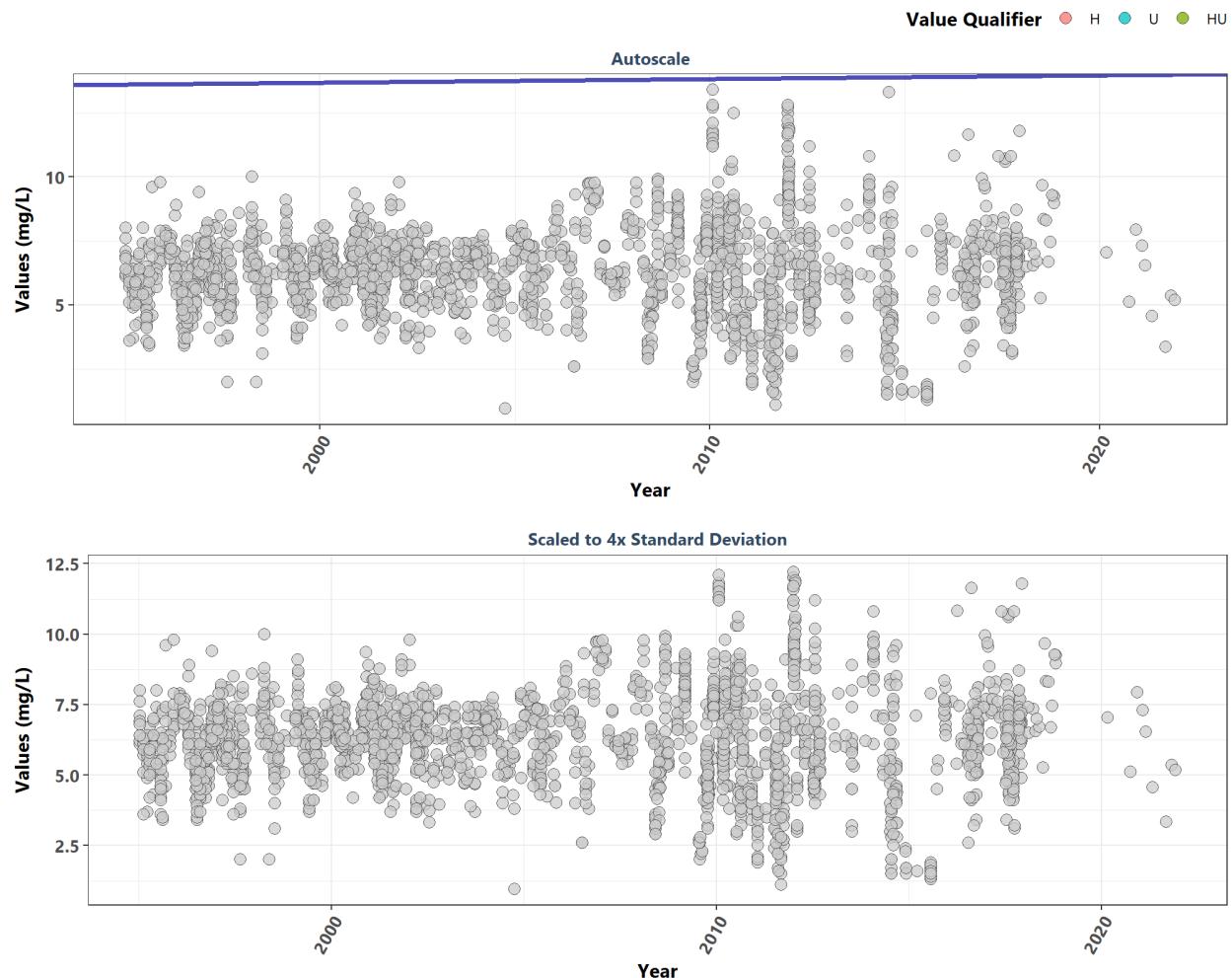
Pellicer Creek Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
56	5.245	-0.0011	-0.0207143	41.99525	0.7394	0

^a p < 0.00005 appear as 0 due to rounding

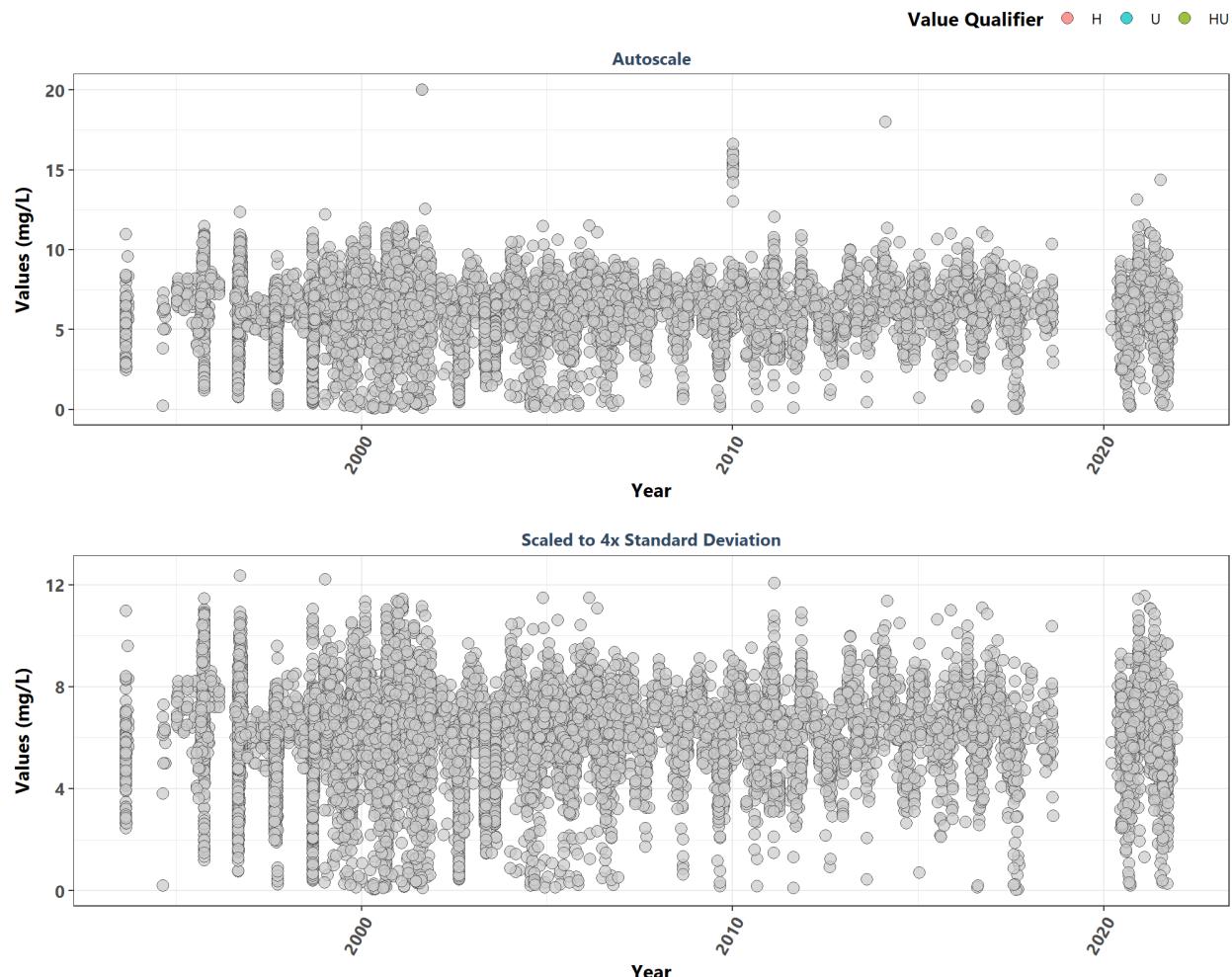
Pine Island Sound Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
2346	6.3	0.0499	0.0142857	-14.88509	0.0022	1

^a p < 0.00005 appear as 0 due to rounding

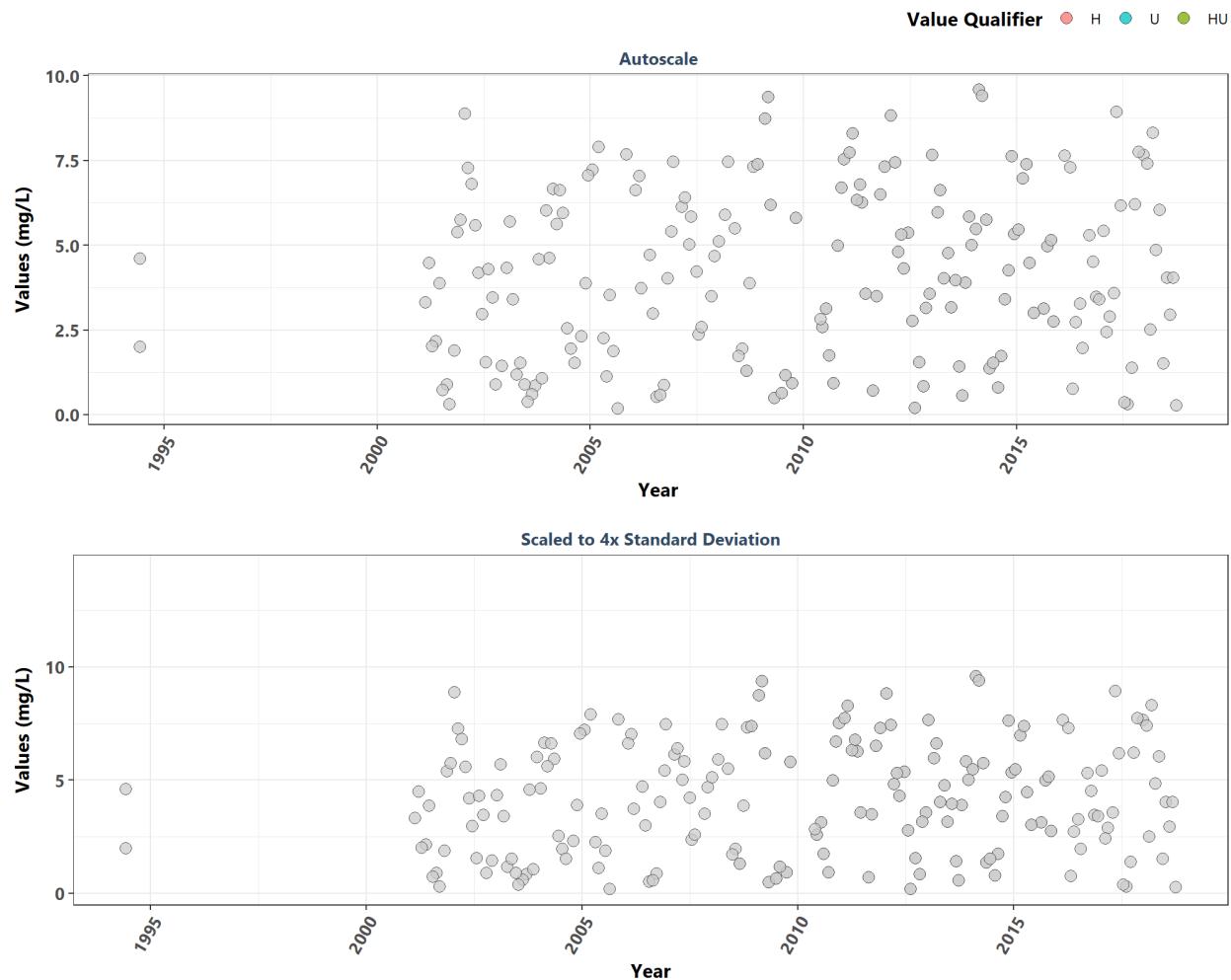
Pinellas County Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
16451	5.89	-0.0051	-0.015	-17.90054	0	-1

^a p < 0.00005 appear as 0 due to rounding

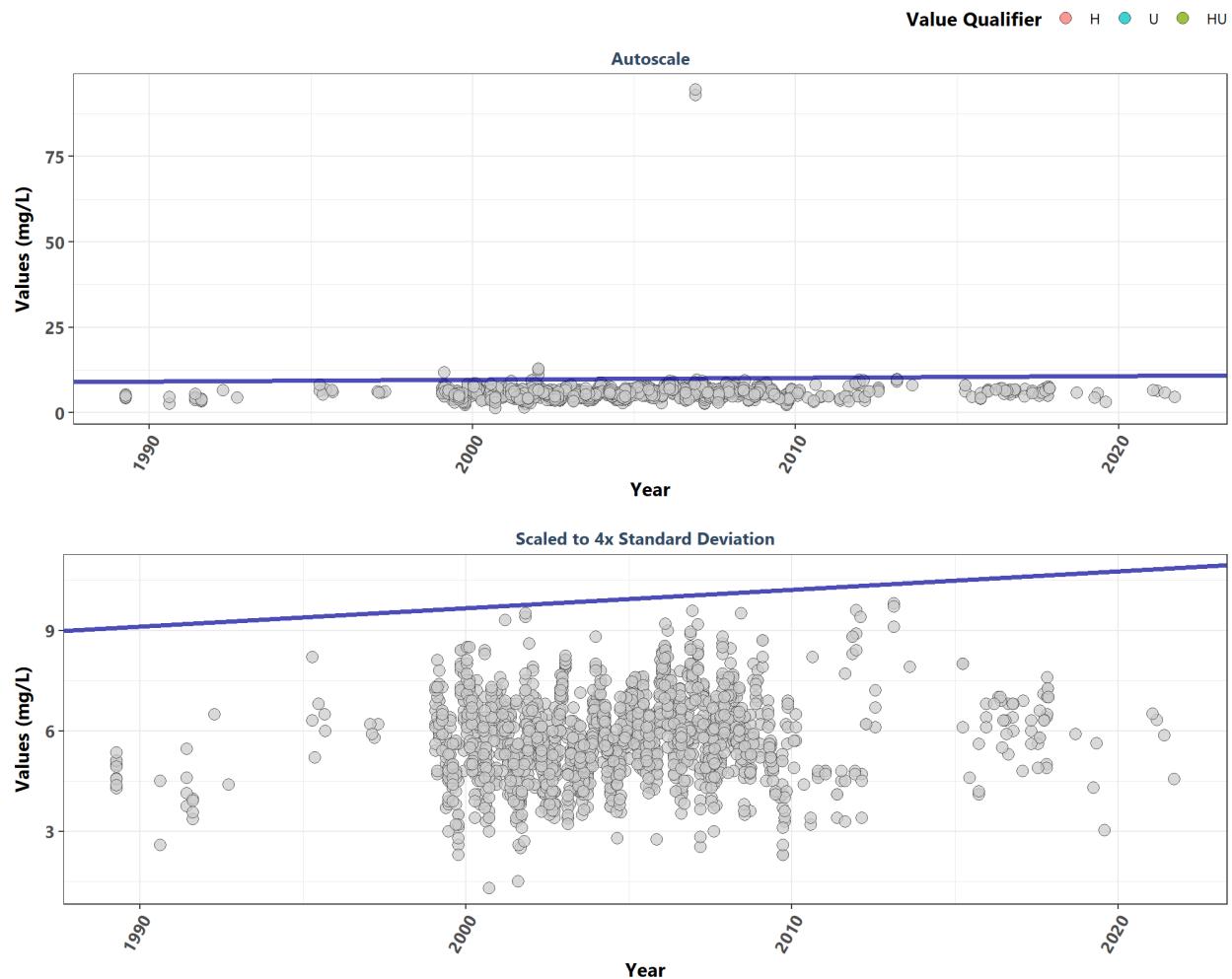
Rocky Bayou State Park Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
260	4.25	0.0997	0.05	-81.45525	0.0185	1

^a p < 0.00005 appear as 0 due to rounding

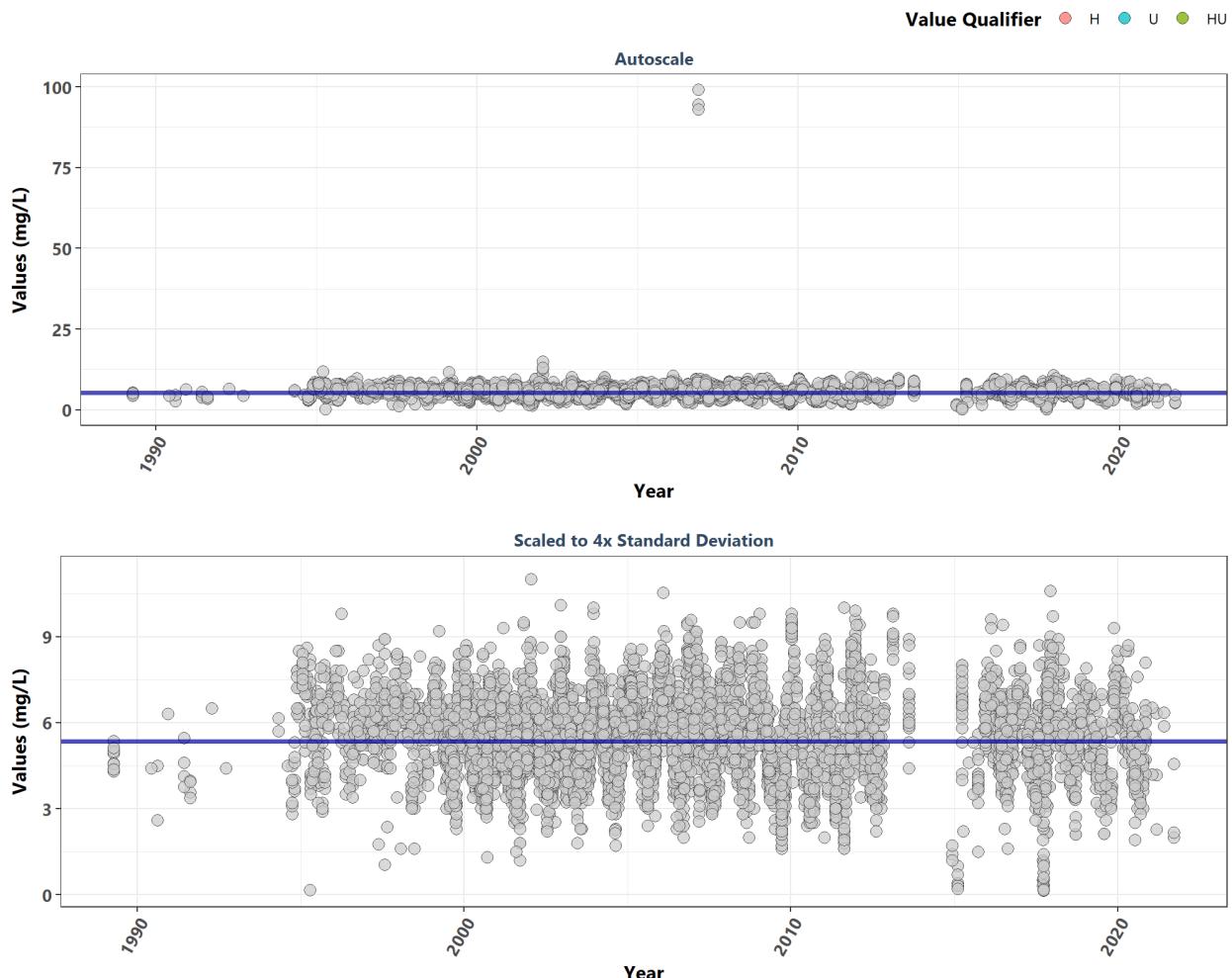
Rookery Bay Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
1661	5.8	0.1273	0.055	-100.3375	0	1

^a p < 0.00005 appear as 0 due to rounding

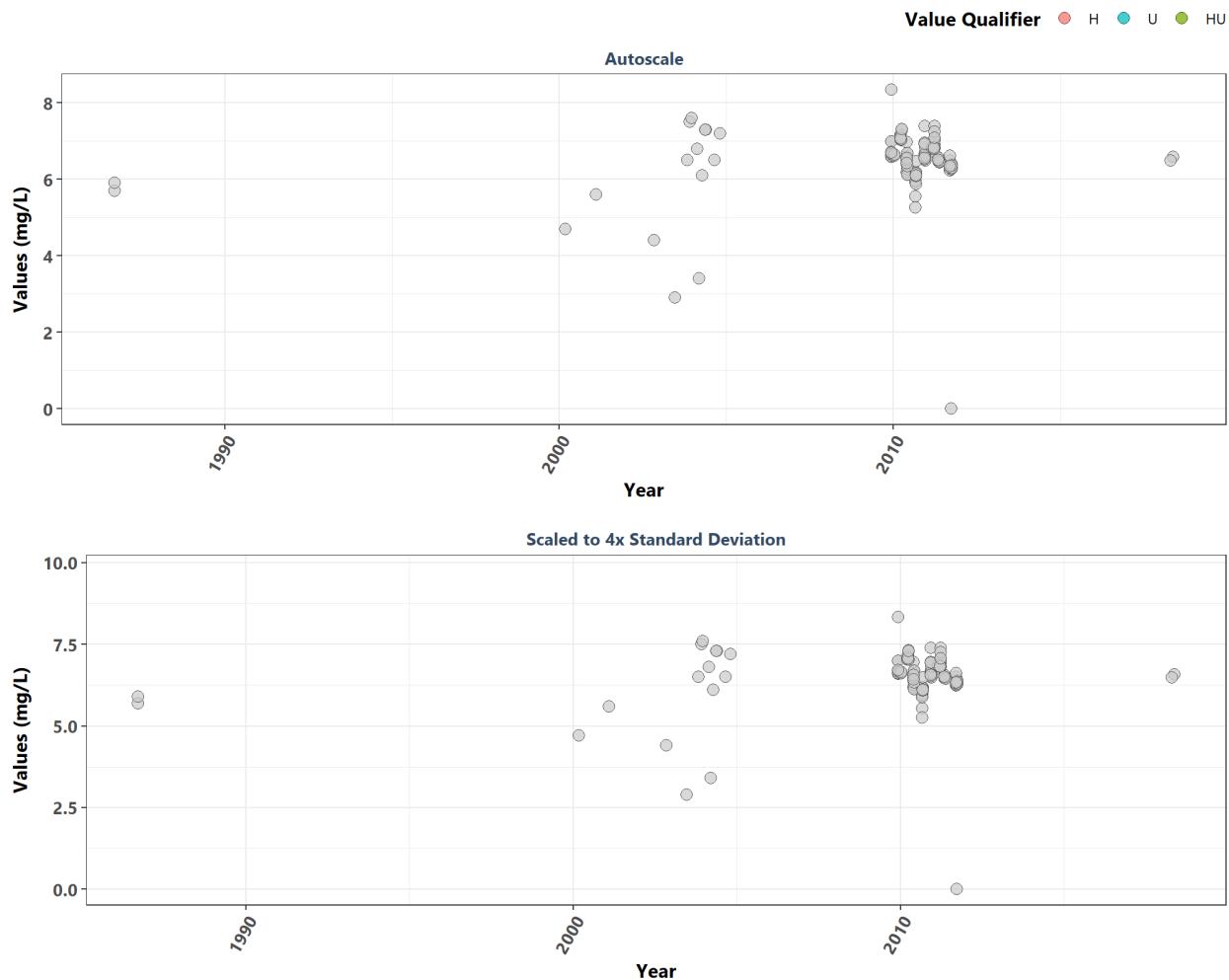
Rookery Bay National Estuarine Research Reserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
6337	5.6	-0.0039	0	5.35	0.3447	0

^a p < 0.00005 appear as 0 due to rounding

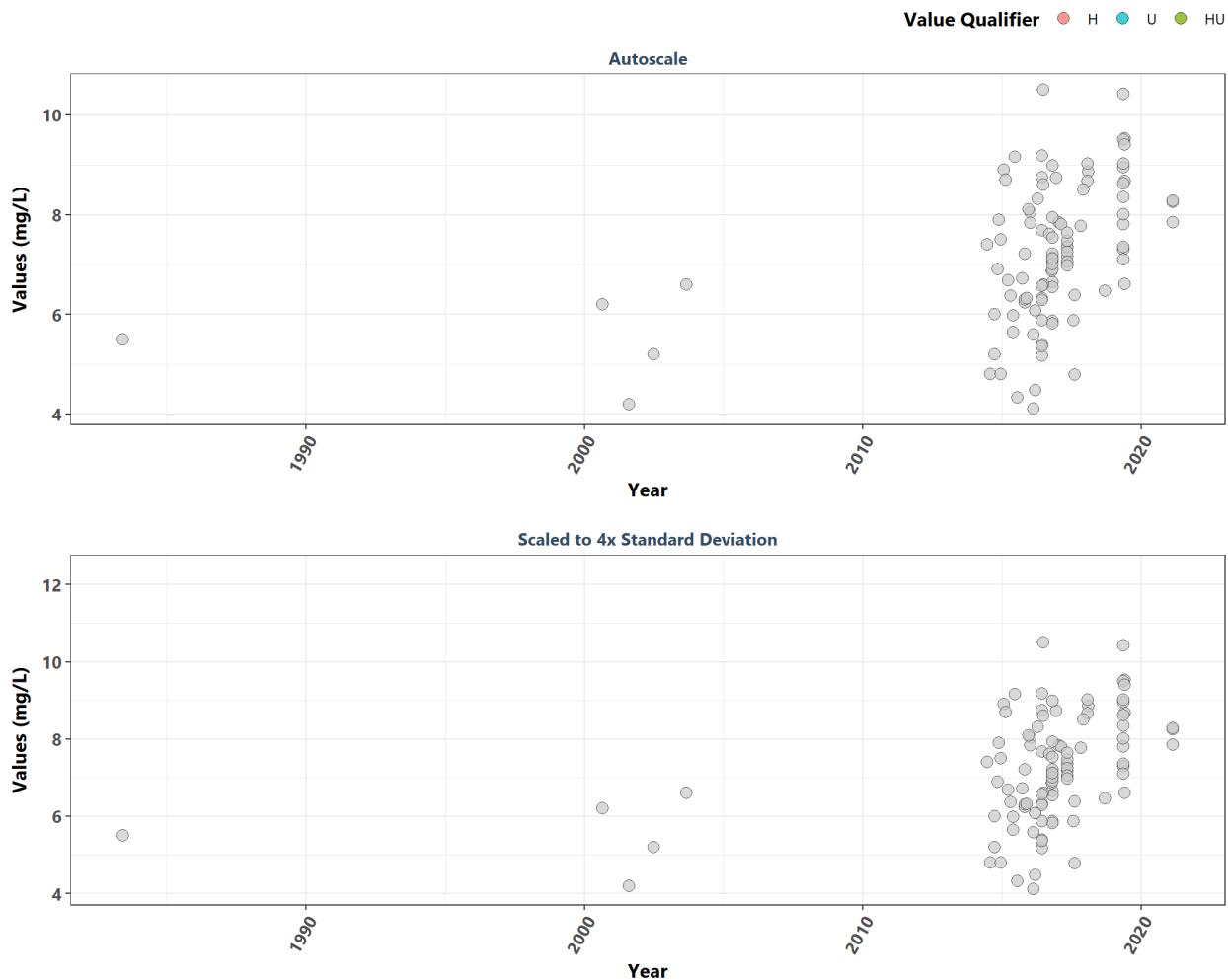
Southeast Florida Coral Reef Ecosystem Conservation Area



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
151	6.5609	0.0421	0.0083762	-223.1651	0.6311	0

^a p < 0.00005 appear as 0 due to rounding

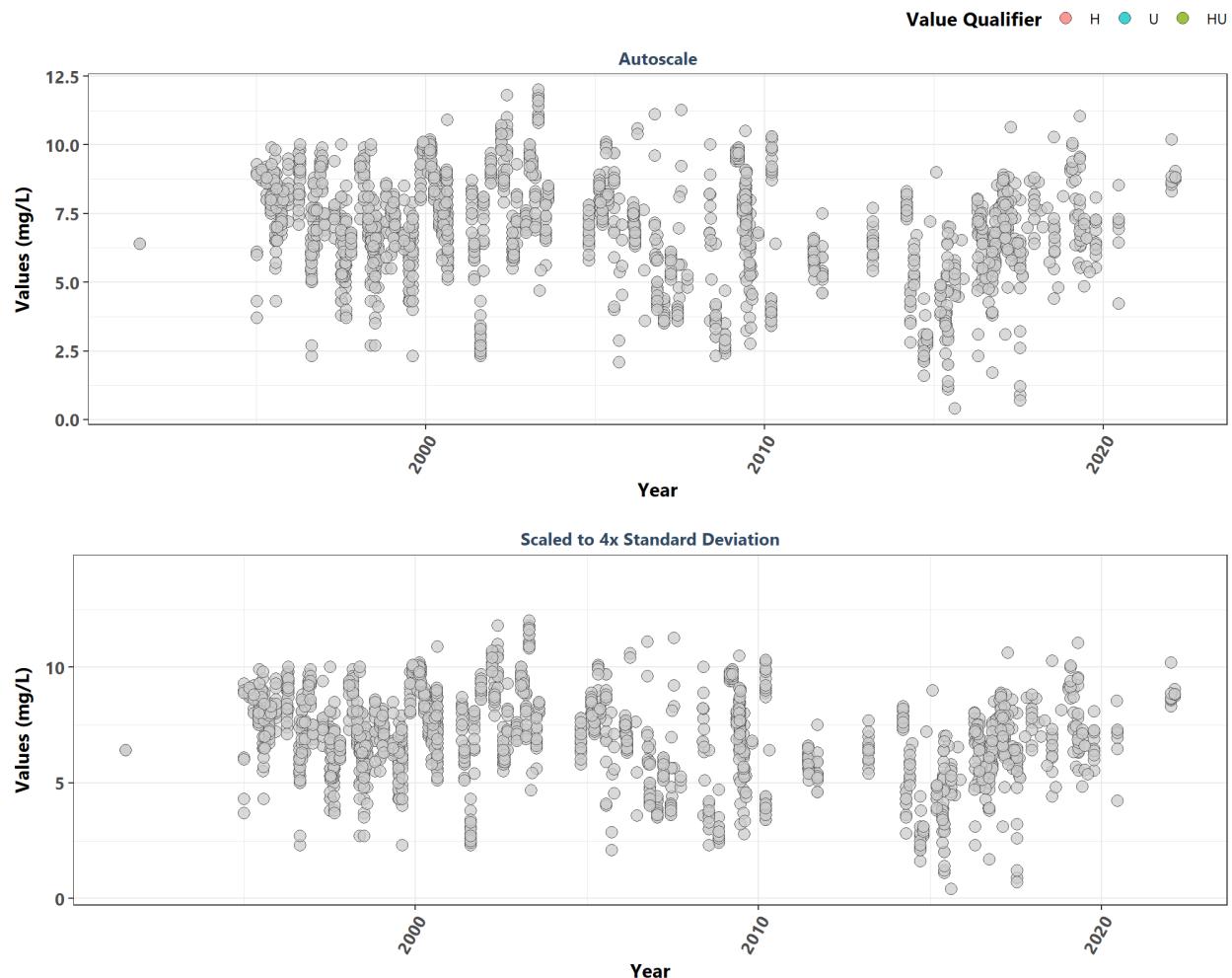
St. Andrews State Park Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
101	7.16	0.2094	0.5	-146.8728	0.0003	1

^a p < 0.00005 appear as 0 due to rounding

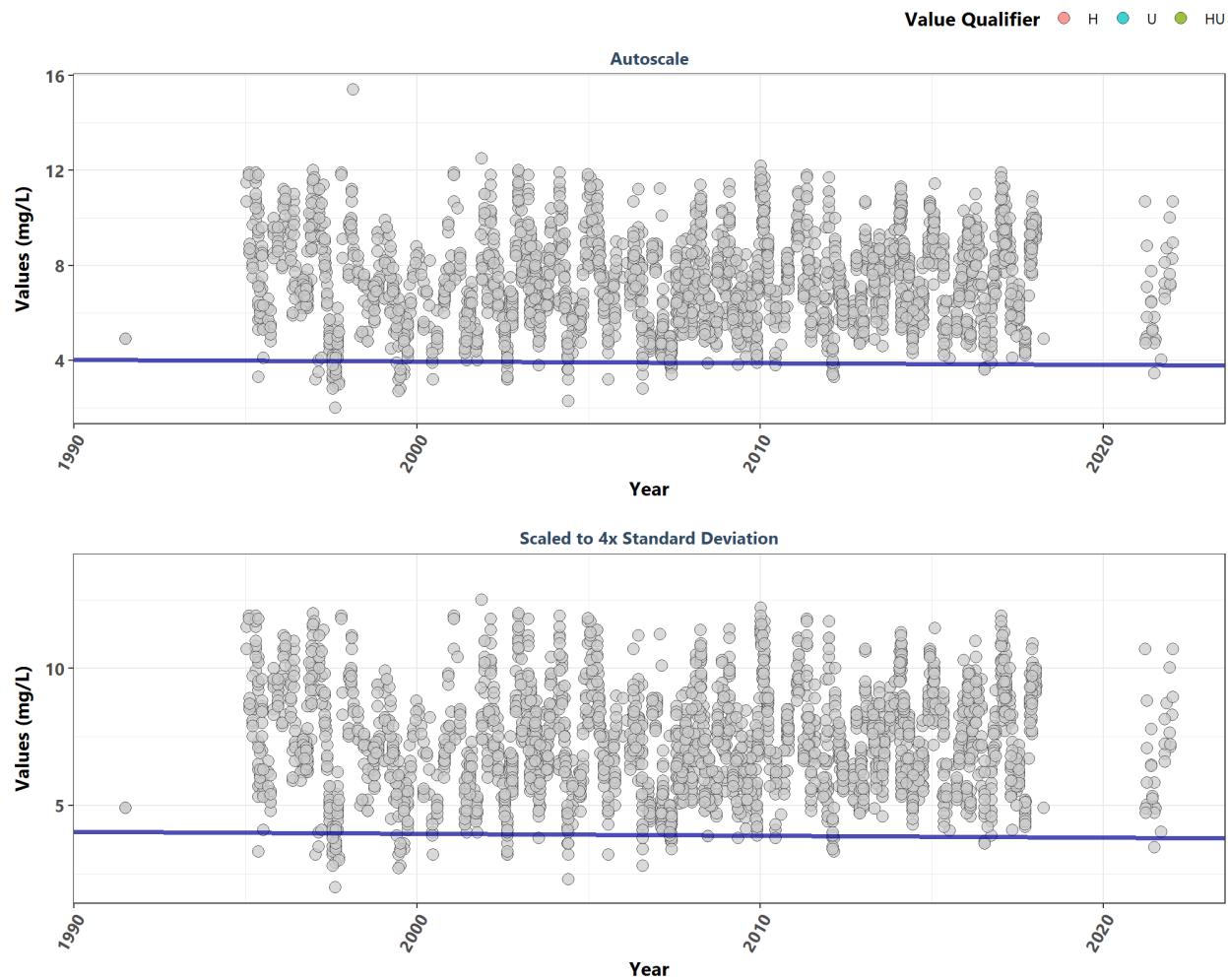
St. Joseph Bay Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
1845	7.12	-0.1953	-0.0681818	128.9708	0	-1

^a p < 0.00005 appear as 0 due to rounding

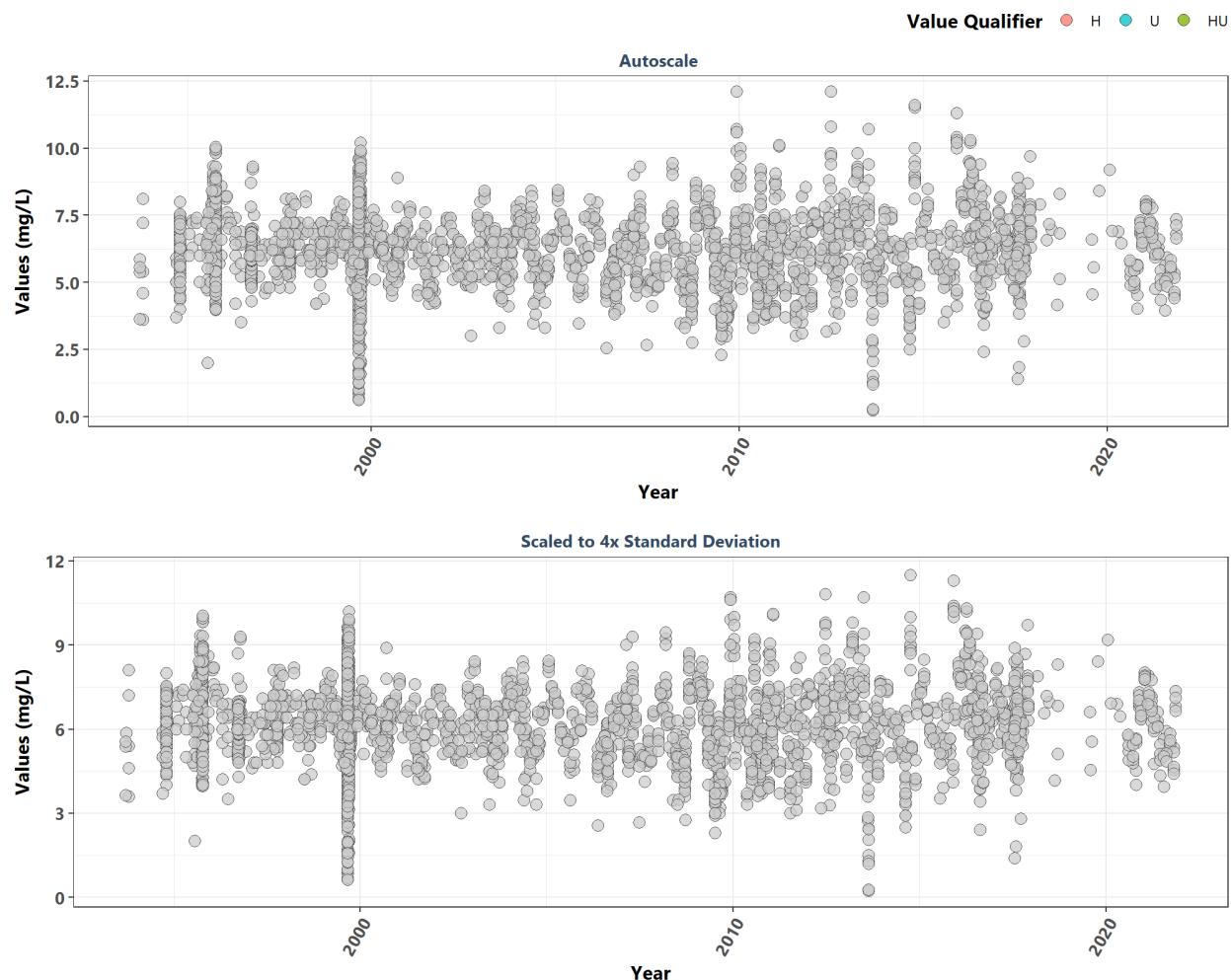
St. Martins Marsh Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
2782	7.2	-0.0063	-0.0071429	18.24444	0.076	0

^a p < 0.00005 appear as 0 due to rounding

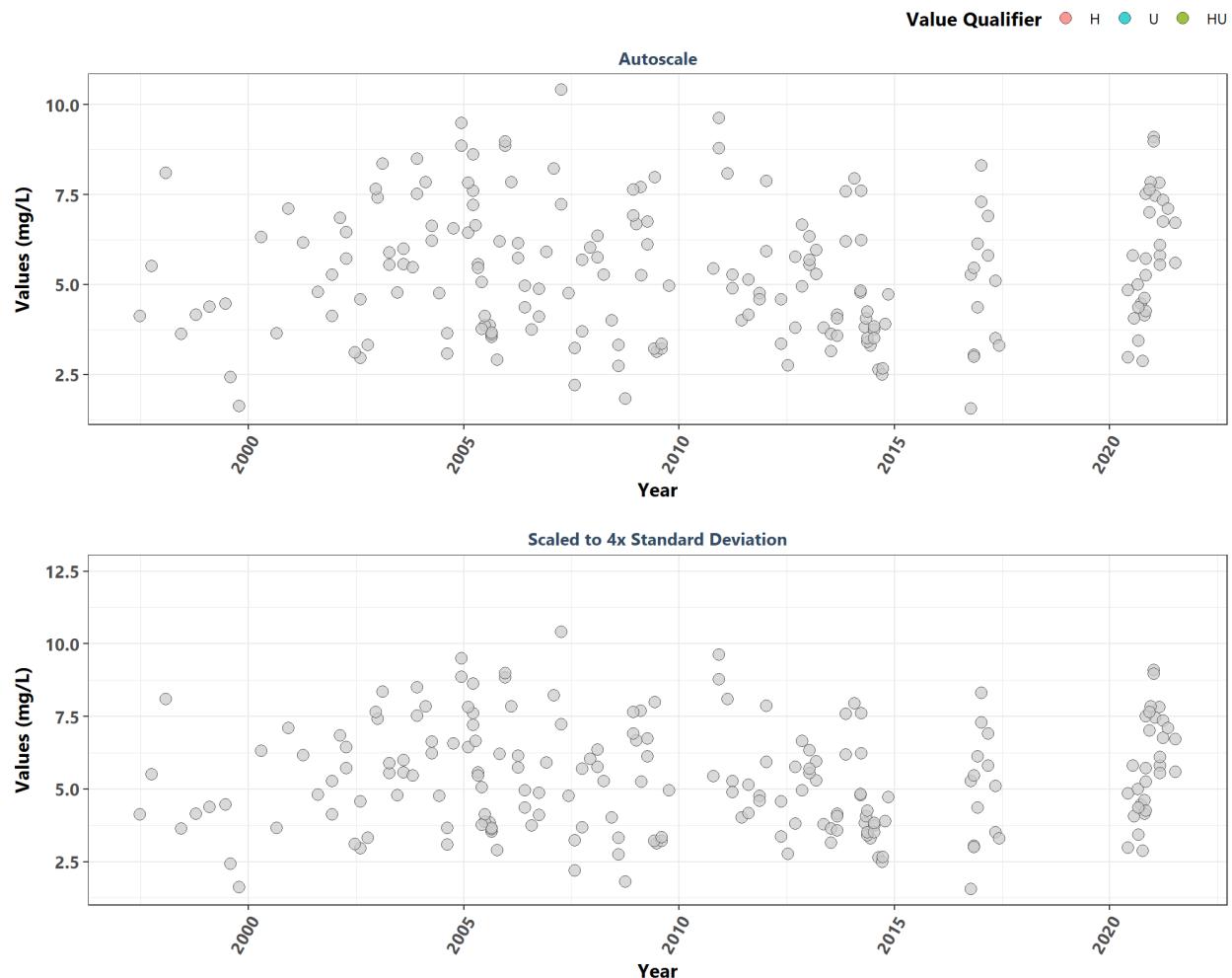
Terra Ceia Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
3264	6.1	-0.0321	-0.0263636	-8.716429	0	-1

^a p < 0.00005 appear as 0 due to rounding

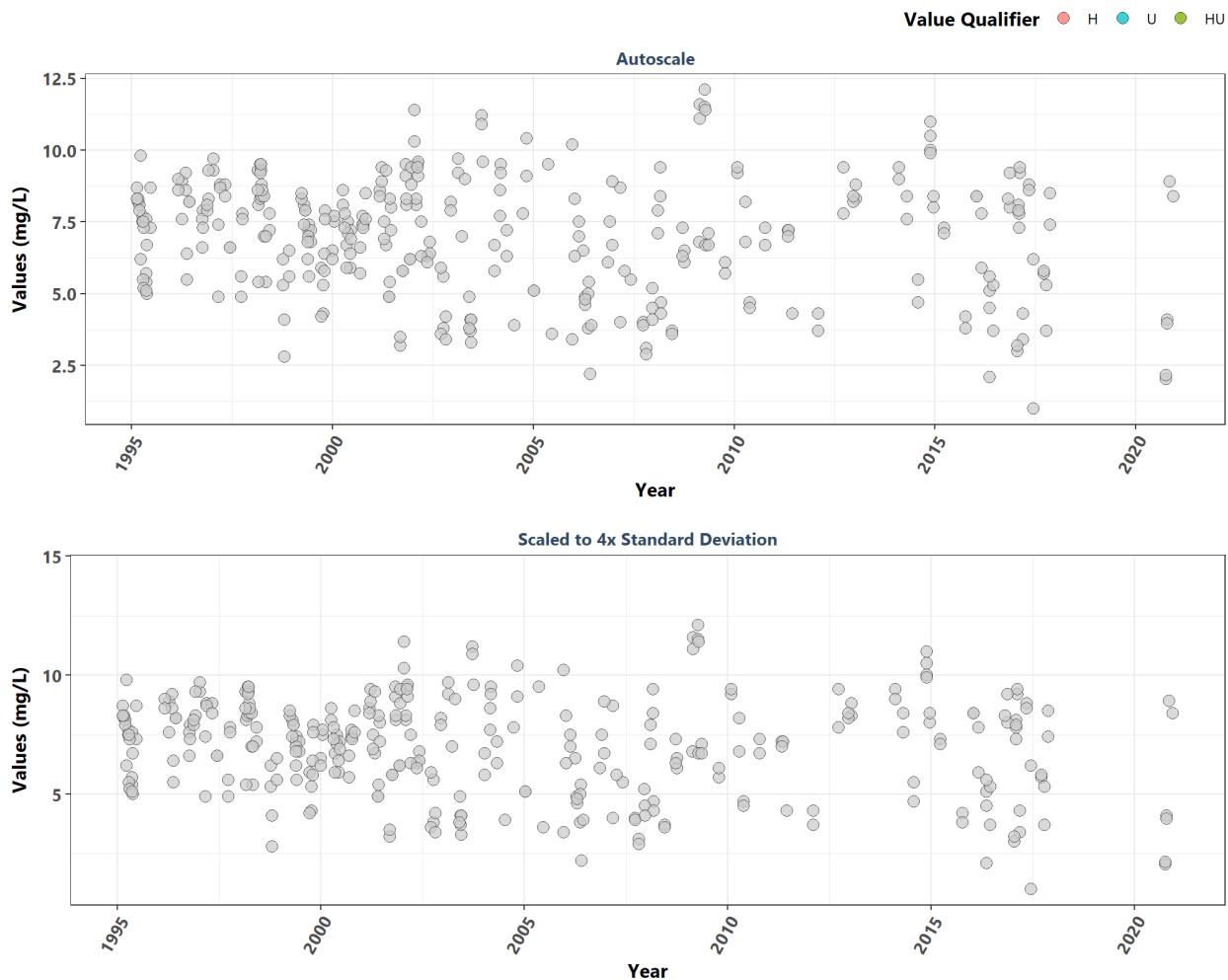
Tomoka Marsh Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
192	5.275	-0.0197	-0.0136364	69.48283	0.4203	0

^a p < 0.00005 appear as 0 due to rounding

Yellow River Marsh Aquatic Preserve



N_Data	Median	tau	SennSlope	SennIntercept	p	Trend
328	7.3	-0.1419	-0.075	62.85515	0	-1

^a p < 0.00005 appear as 0 due to rounding

Appendix V: Managed Area Summary Box Plots

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

1. Use the data set that only has SufficientData of TRUE for the desired managed area
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 `ManagedAreaName` with data grouped by `Year`, then `Year` and `Month`, then finally `Month` only. Each managed 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 managed areas that qualify.")
} else {
  for (i in 1:n) {
    plot_data <- data[data$SufficientData==TRUE &
                      data$ManagedAreaName==MA_Include[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$ResultValue <
                                             quantile(data$ResultValue, 0.98)])
    sd_RV <- sd(plot_data$ResultValue[plot_data$ResultValue <
                                             quantile(data$ResultValue, 0.98)])
    x_scale <- ifelse(year_upper - year_lower > 30, 10, 5)
    y_scale <- mn_RV + 4 * sd_RV

    ##Year plots
    p1 <- ggplot(data=plot_data,
                  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=plot_data,
                  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=plot_data[plot_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(MA_Include[i]),
  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=plot_data,
  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=plot_data,
  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=plot_data[plot_data$Year >= year_upper - 10, ],
  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(MA_Include[i]),
                        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=plot_data,
              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=plot_data,
              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=plot_data[plot_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))

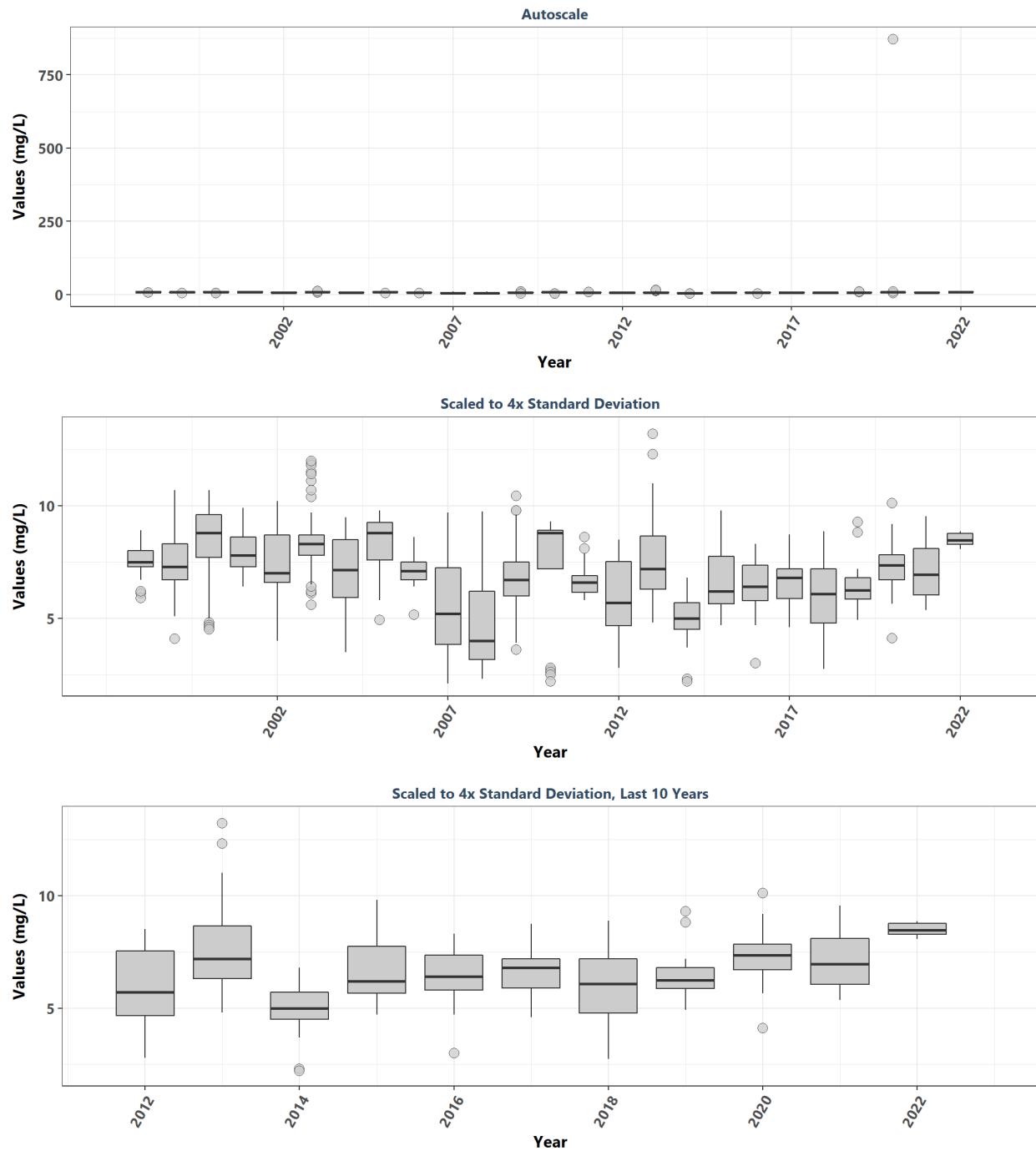
p000 <- ggplot() + labs(title=paste0(MA_Include[i]),
                         subtitle="By Month") + plot_theme +
  theme(panel.border=element_blank(),
        panel.grid.major=element_blank(),
        panel.grid.minor=element_blank(), axis.line=element_blank())

print(ggarrange(p0, Yset, ncol=1, heights=c(0.07, 1)))
print(ggarrange(p00, YMset, ncol=1, heights=c(0.07, 1)))
print(ggarrange(p000, Mset, ncol=1, heights=c(0.07, 1, 0.7)))

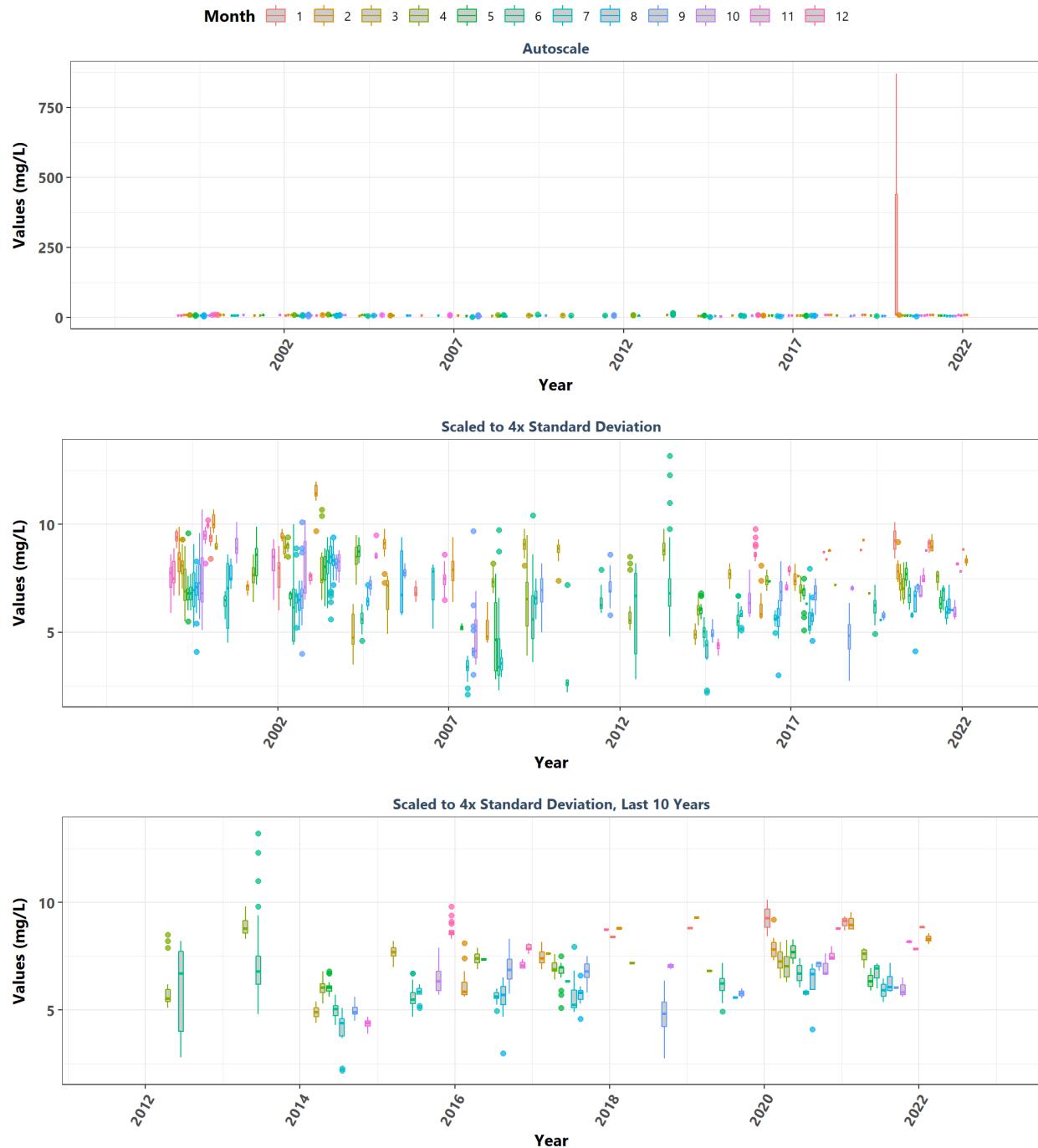
rm(plot_data)
rm(p1, p2, p3, p4, p5, p6, p7, p8, p9, p0, p00, p000, leg1, leg2,
  Yset, YMset, Mset)
}
}

```

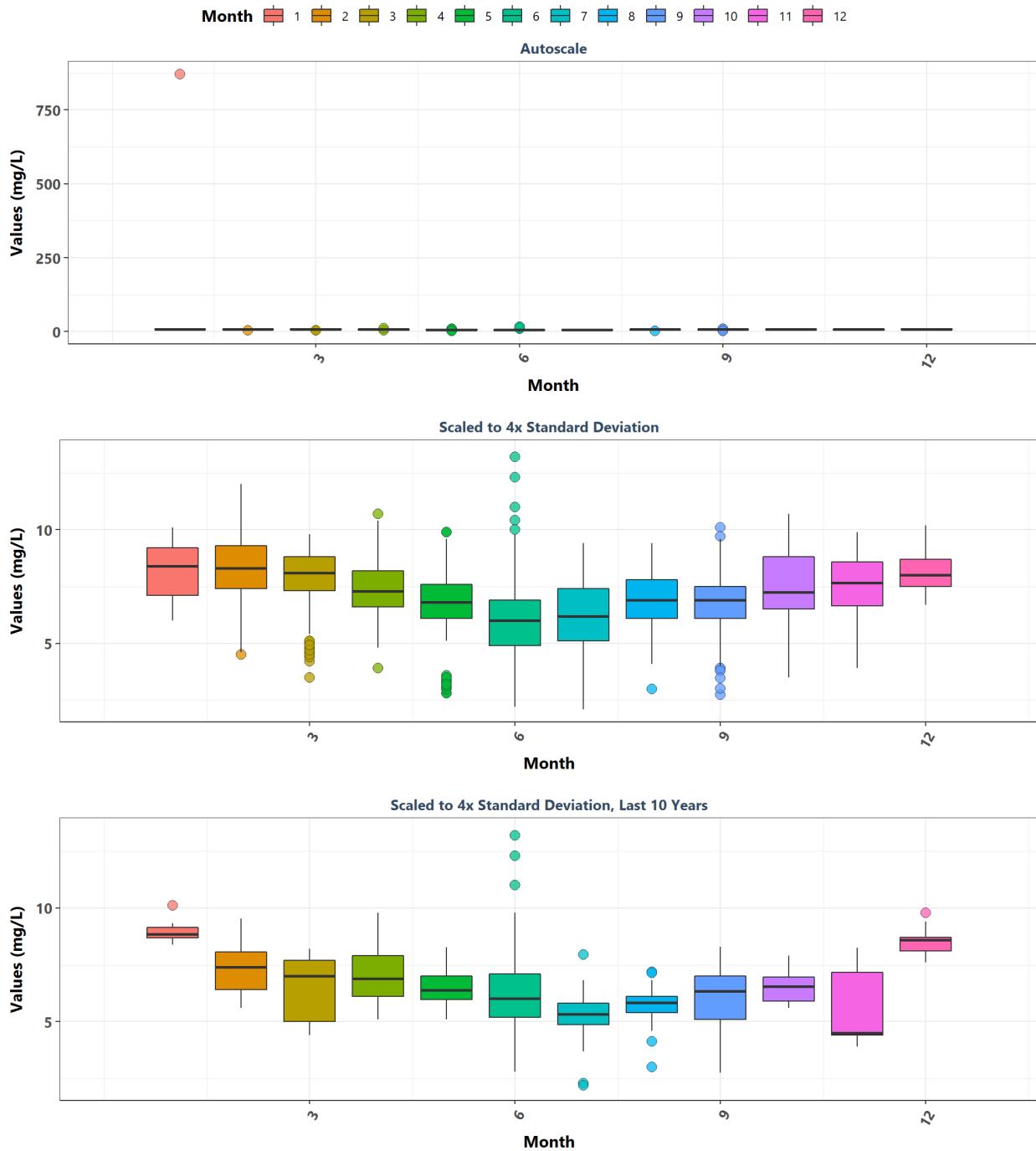
Alligator Harbor Aquatic Preserve
By Year



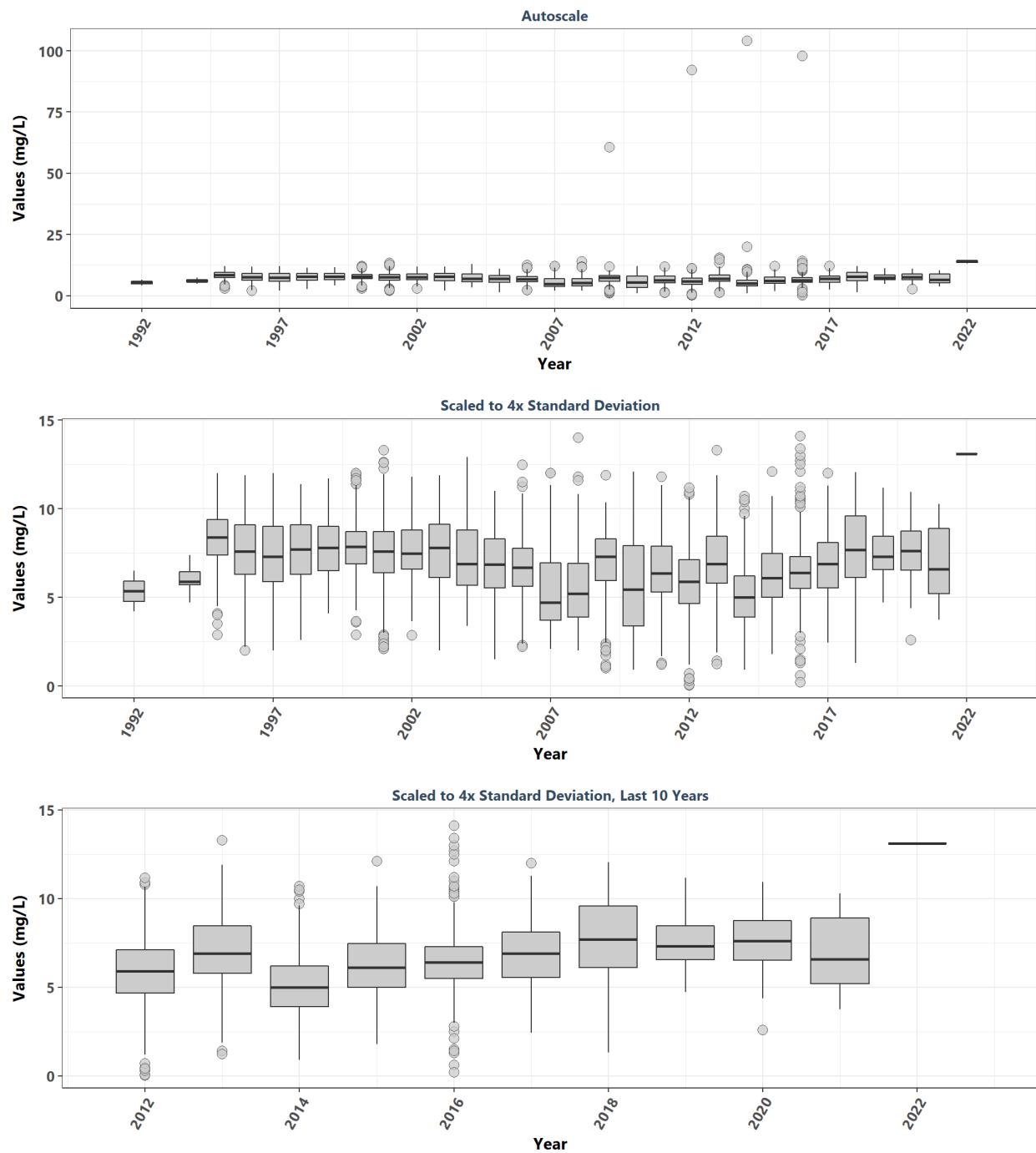
Alligator Harbor Aquatic Preserve
By Year & Month



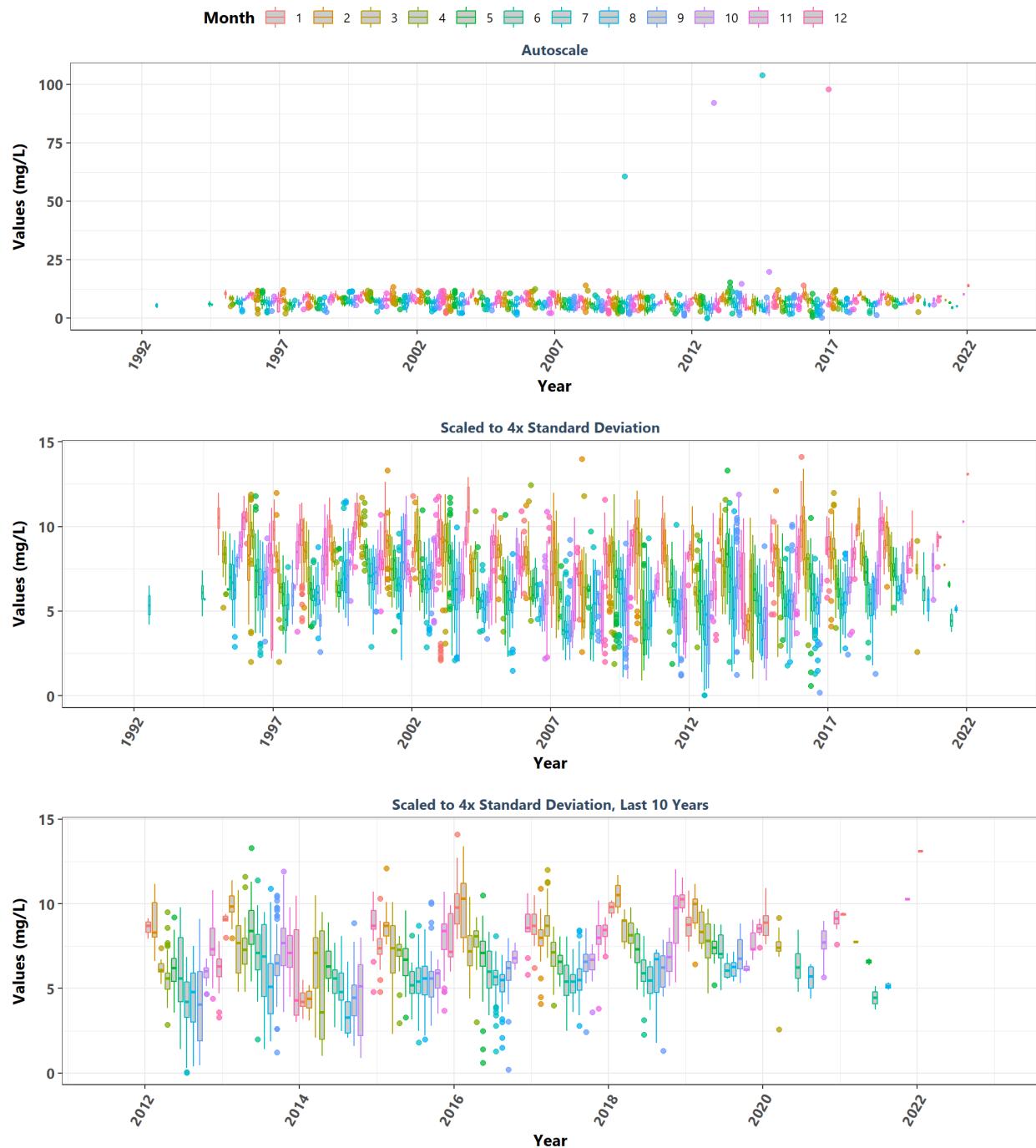
Alligator Harbor Aquatic Preserve
By Month



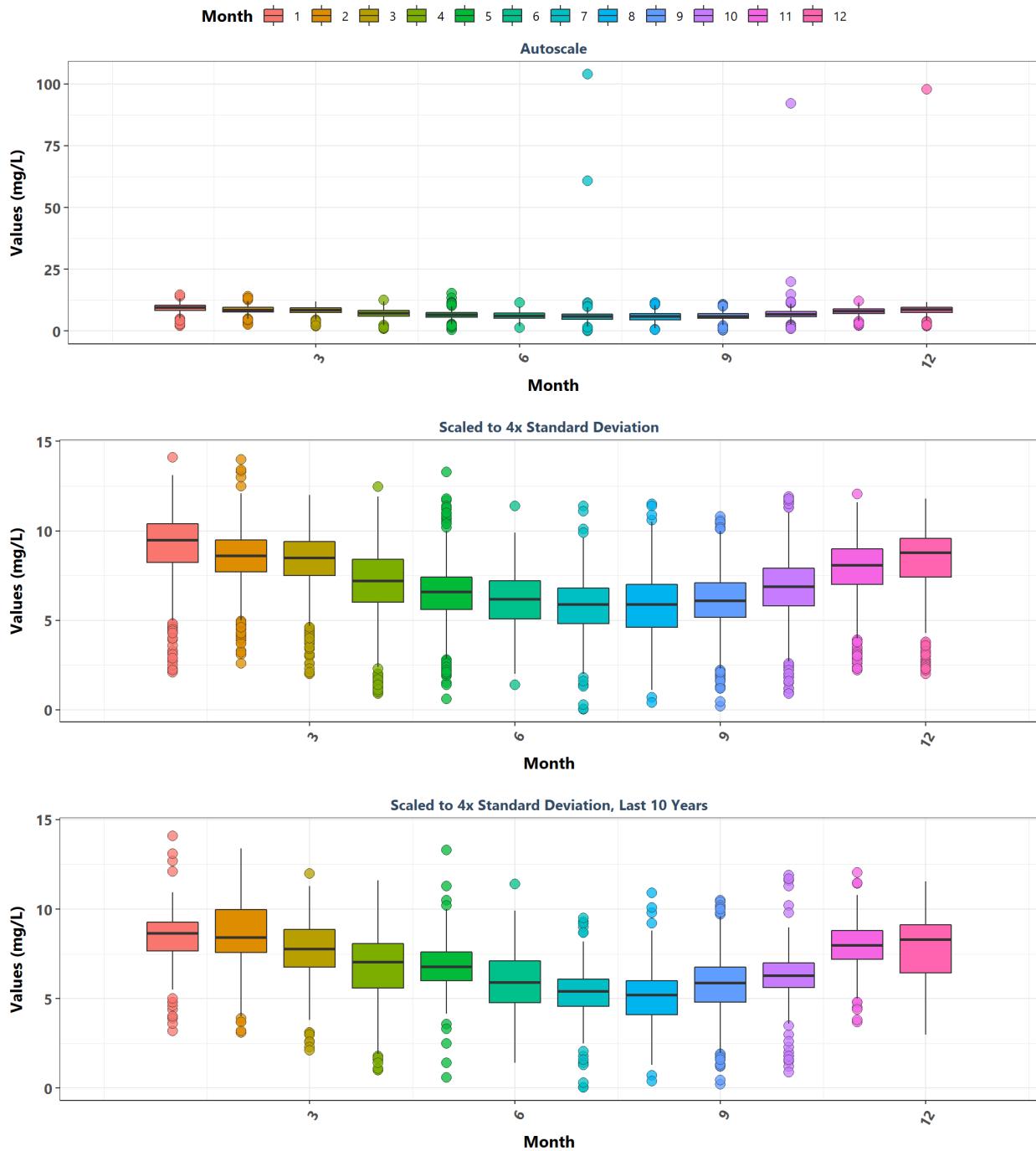
Apalachicola Bay Aquatic Preserve
By Year



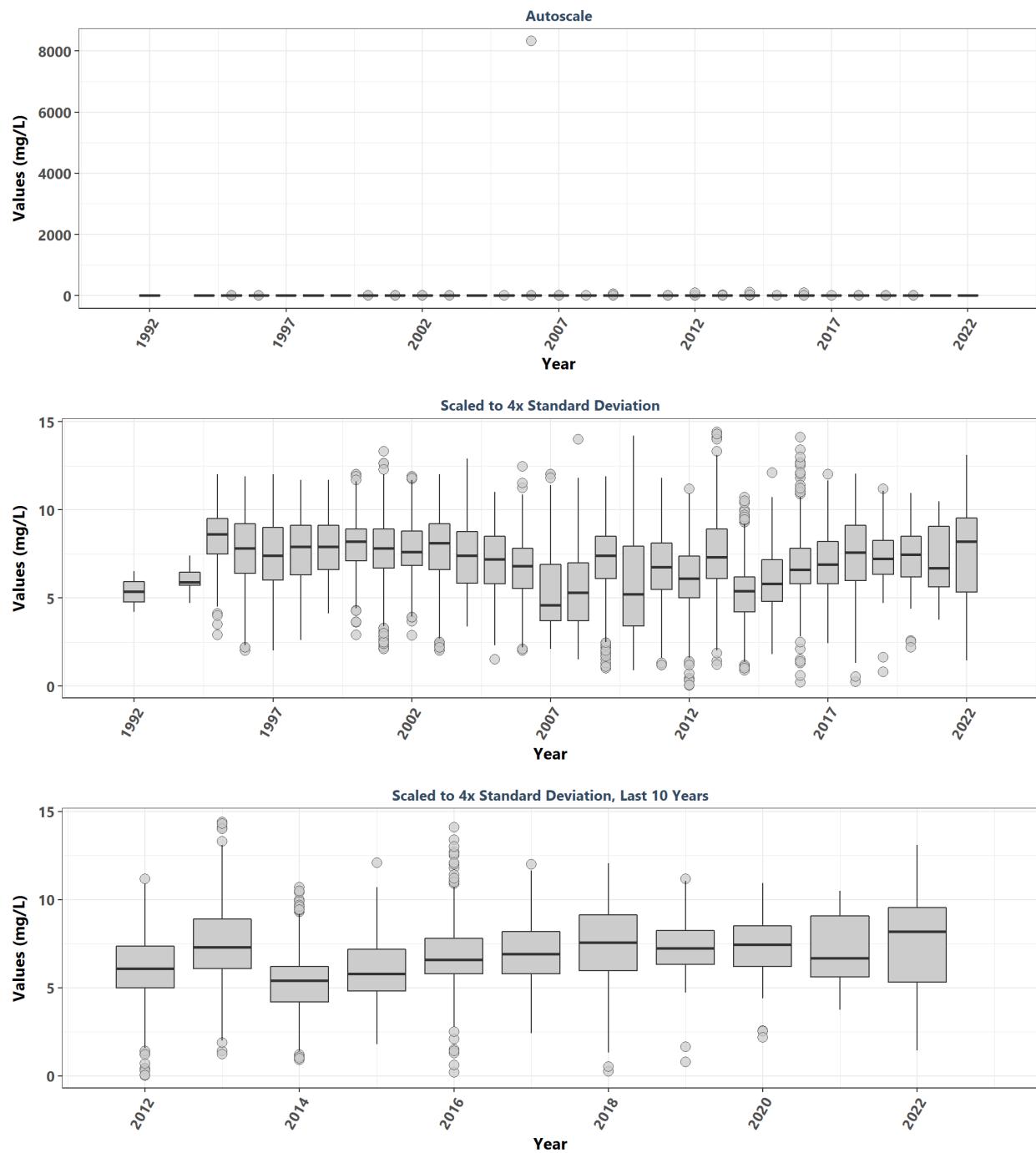
Apalachicola Bay Aquatic Preserve
By Year & Month



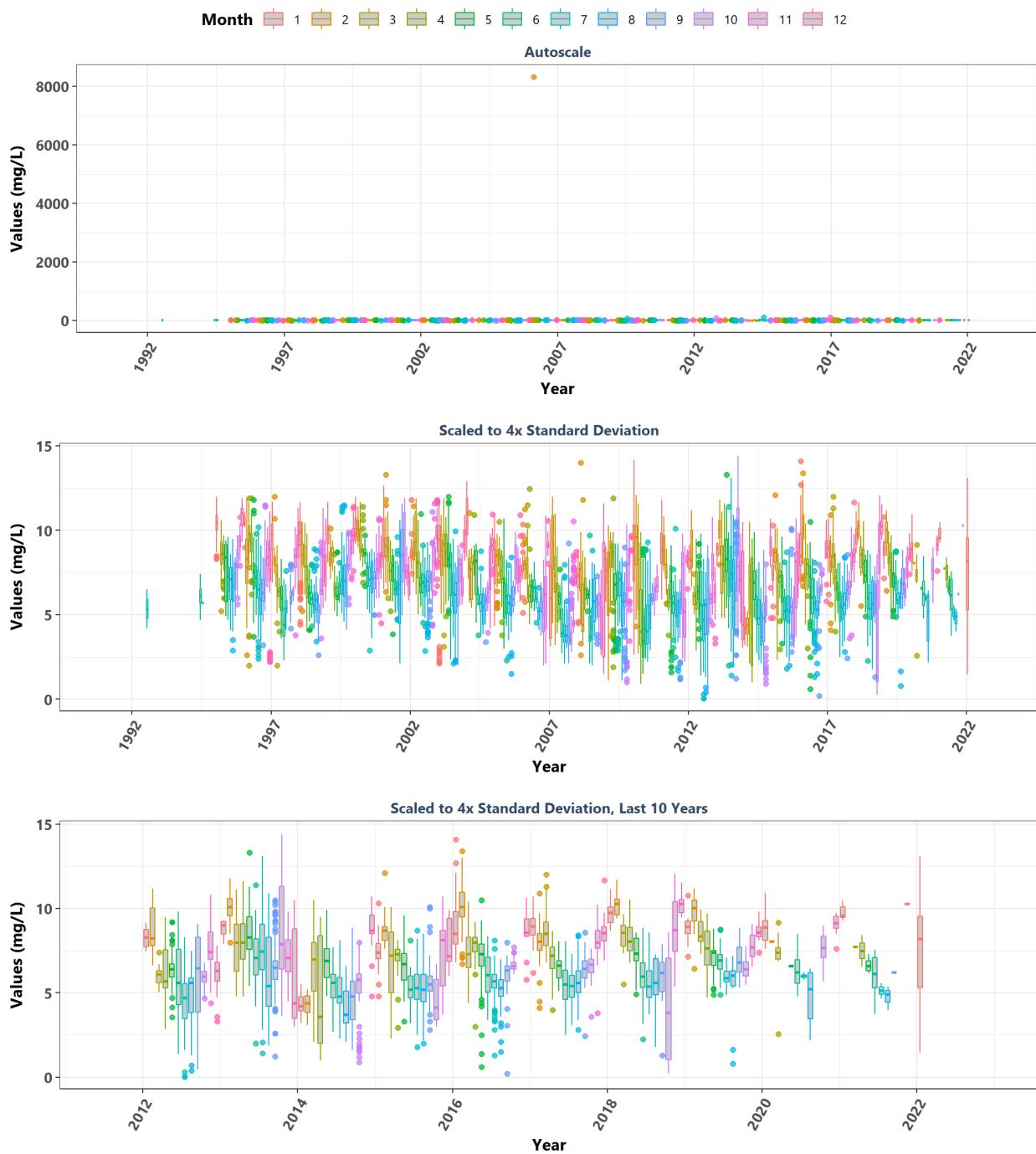
Apalachicola Bay Aquatic Preserve
By Month



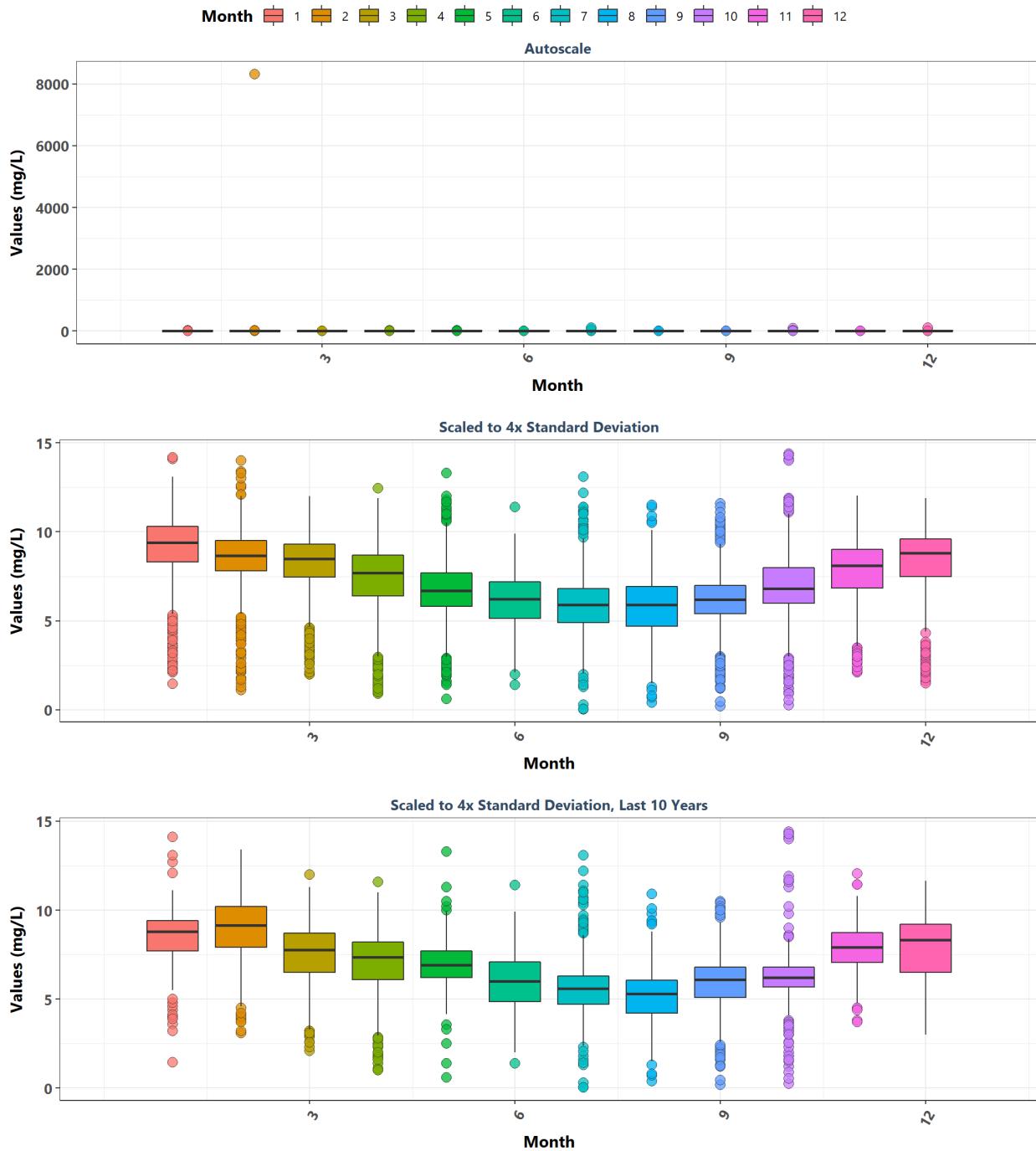
Apalachicola National Estuarine Research Reserve
By Year



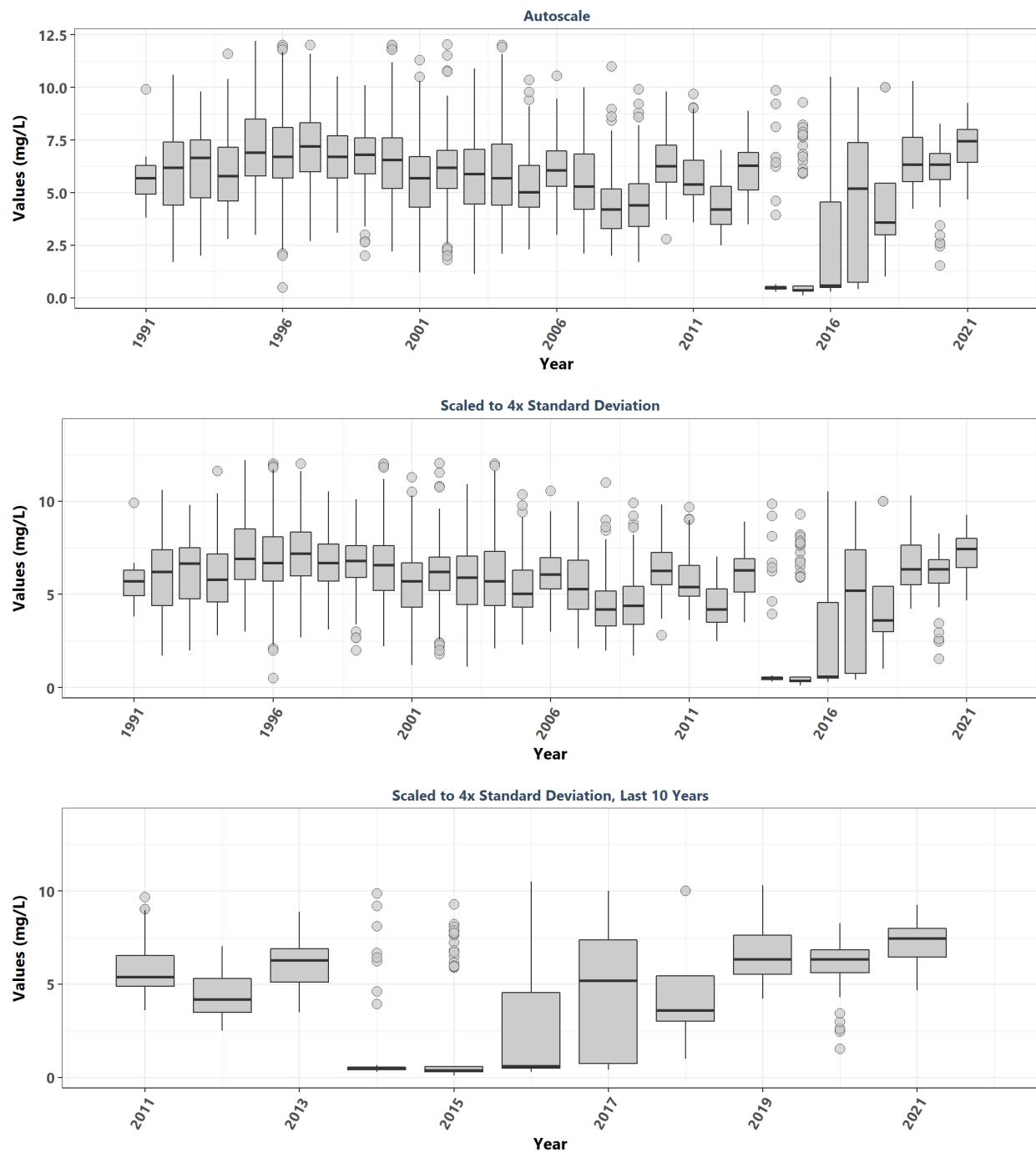
Apalachicola National Estuarine Research Reserve
By Year & Month



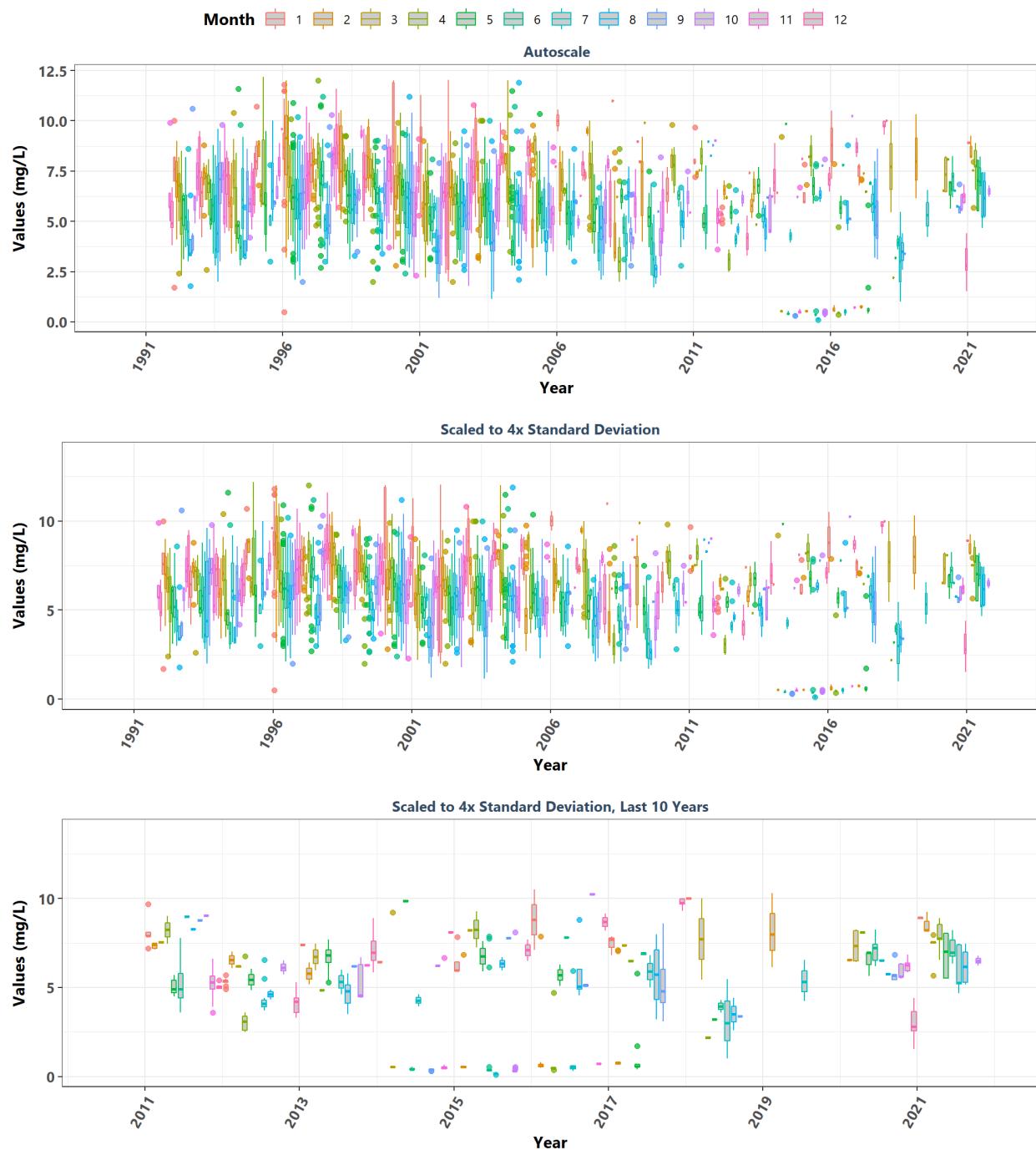
Apalachicola National Estuarine Research Reserve
By Month



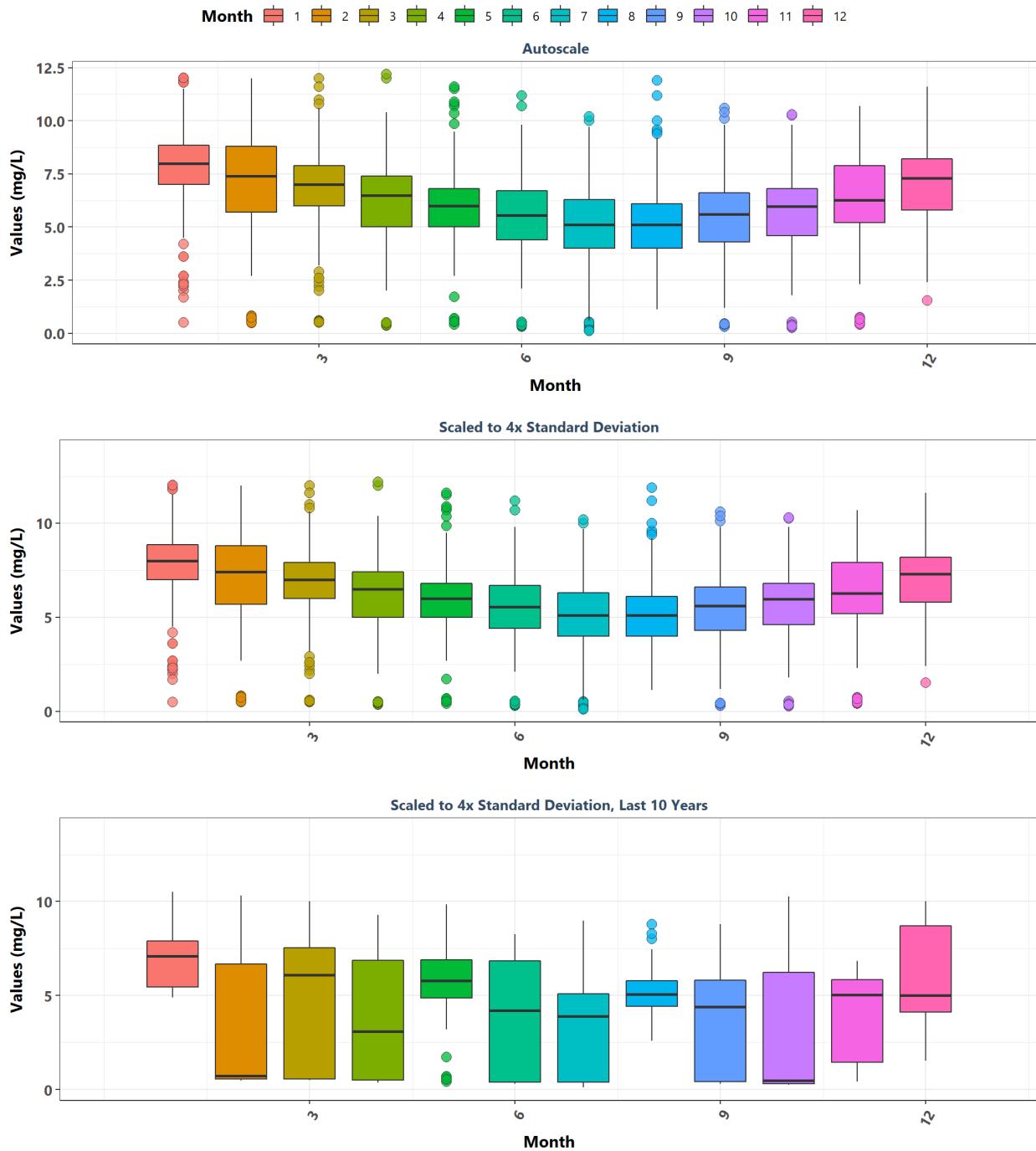
Banana River Aquatic Preserve
By Year



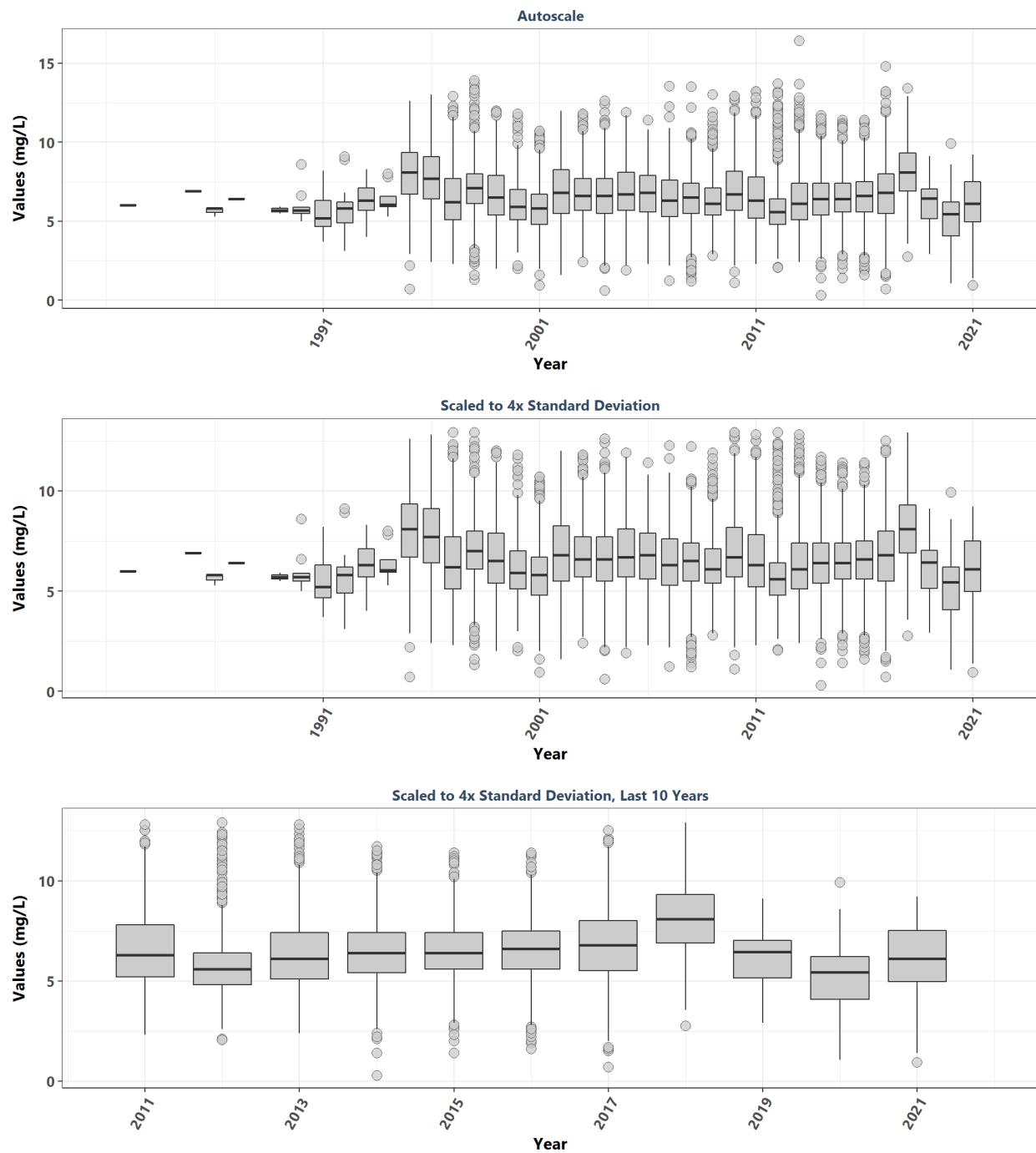
Banana River Aquatic Preserve
By Year & Month



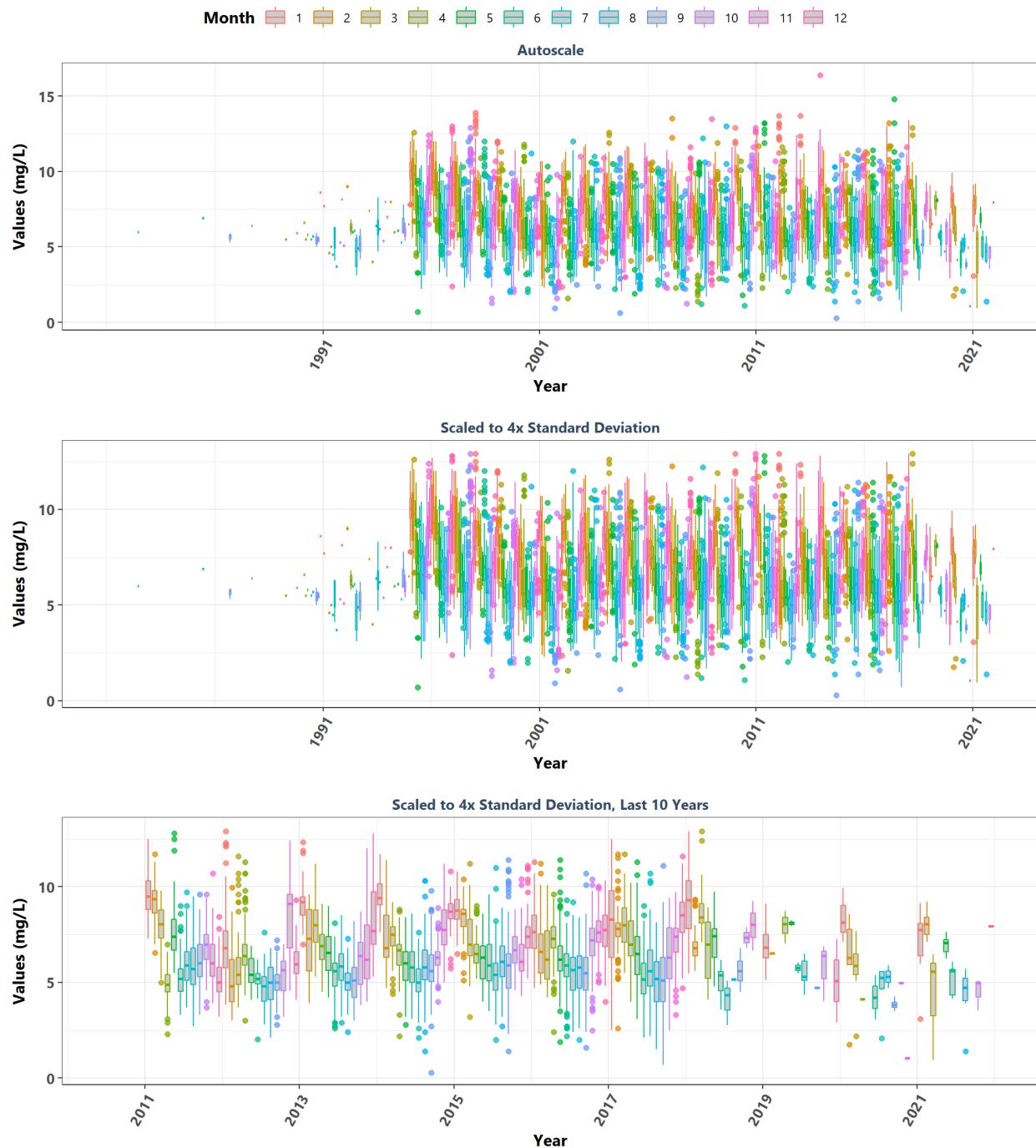
Banana River Aquatic Preserve
By Month



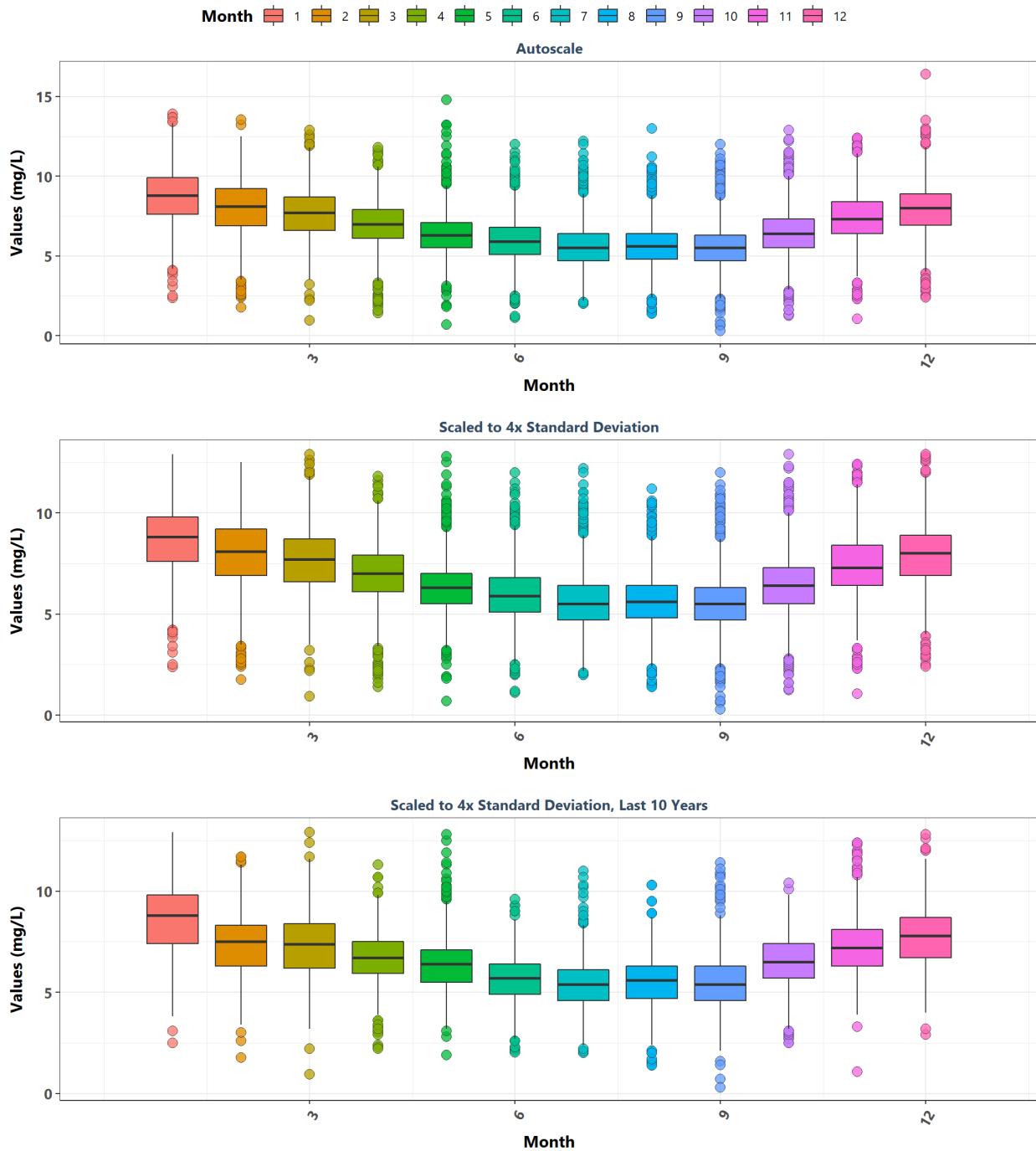
Big Bend Seagrasses Aquatic Preserve
By Year



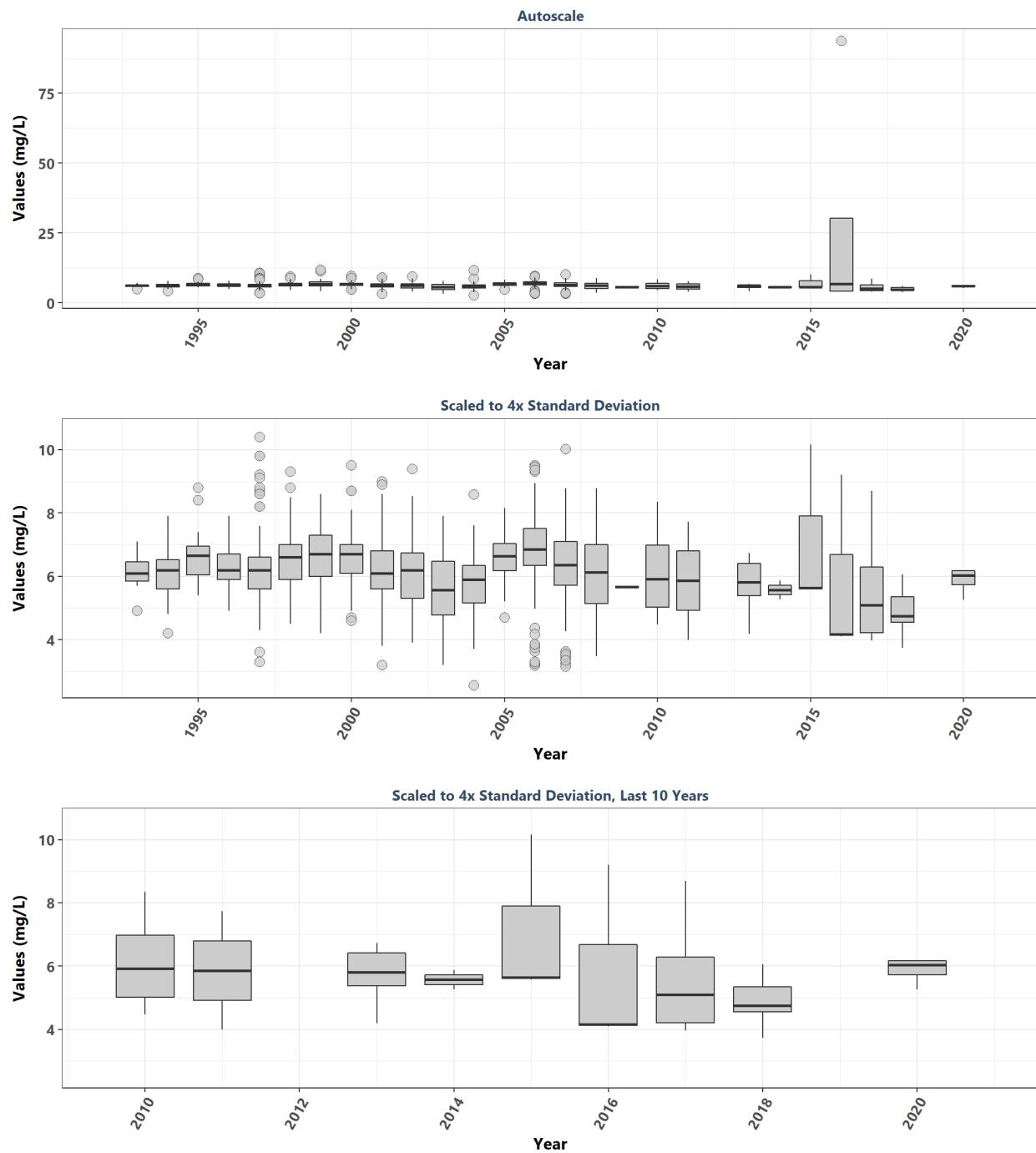
Big Bend Seagrasses Aquatic Preserve
By Year & Month



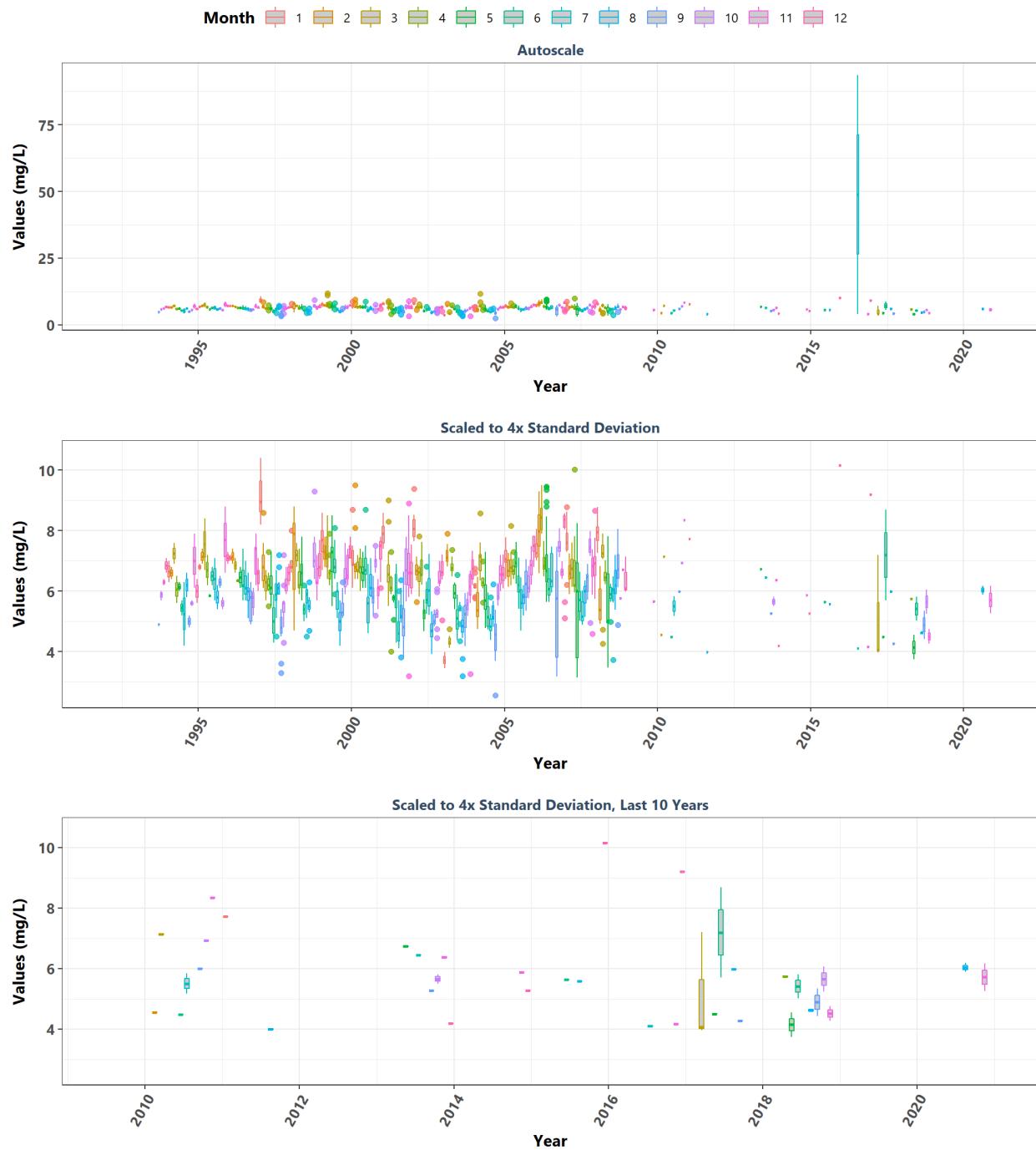
Big Bend Seagrasses Aquatic Preserve
By Month



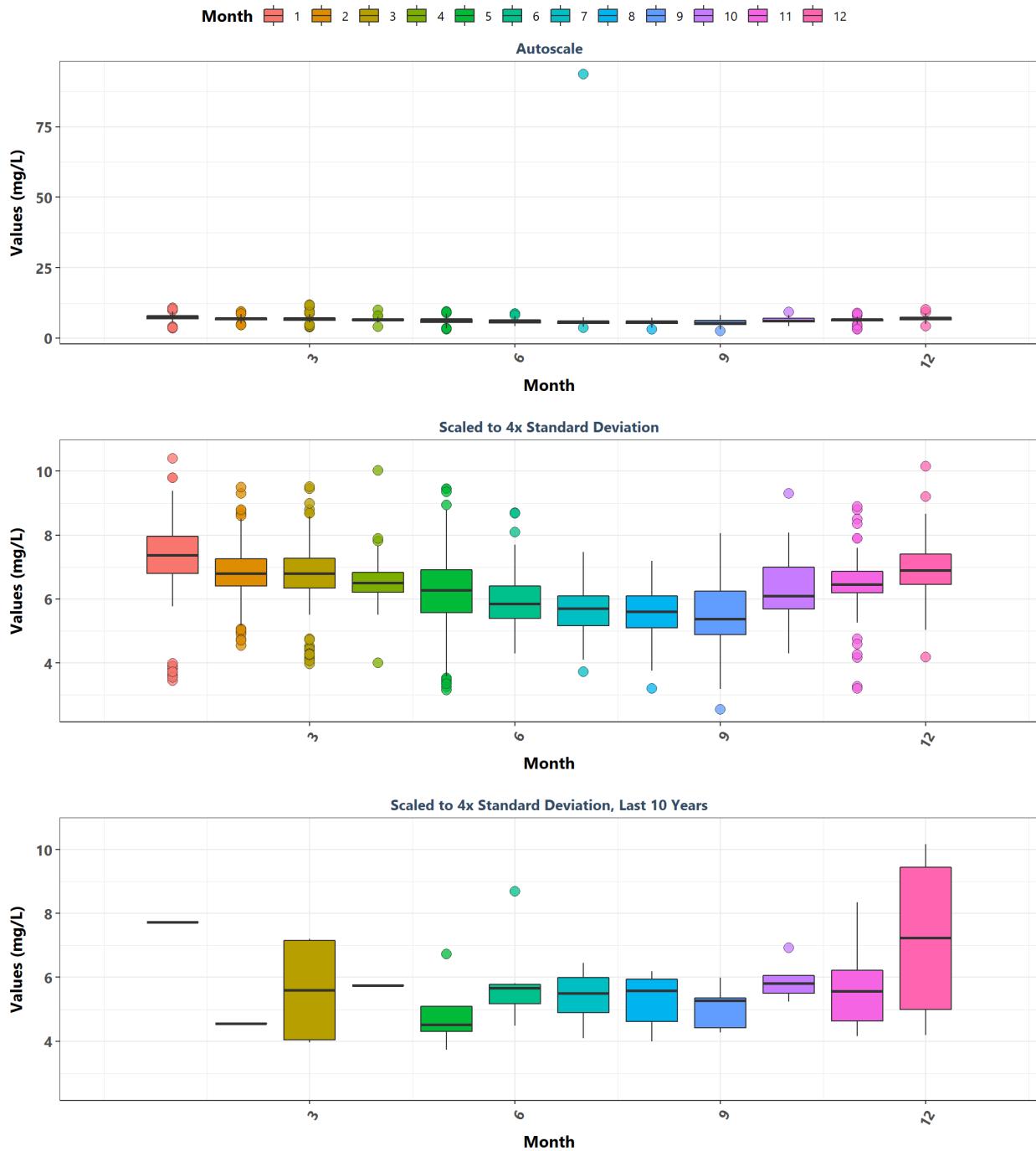
Biscayne Bay Aquatic Preserve
By Year



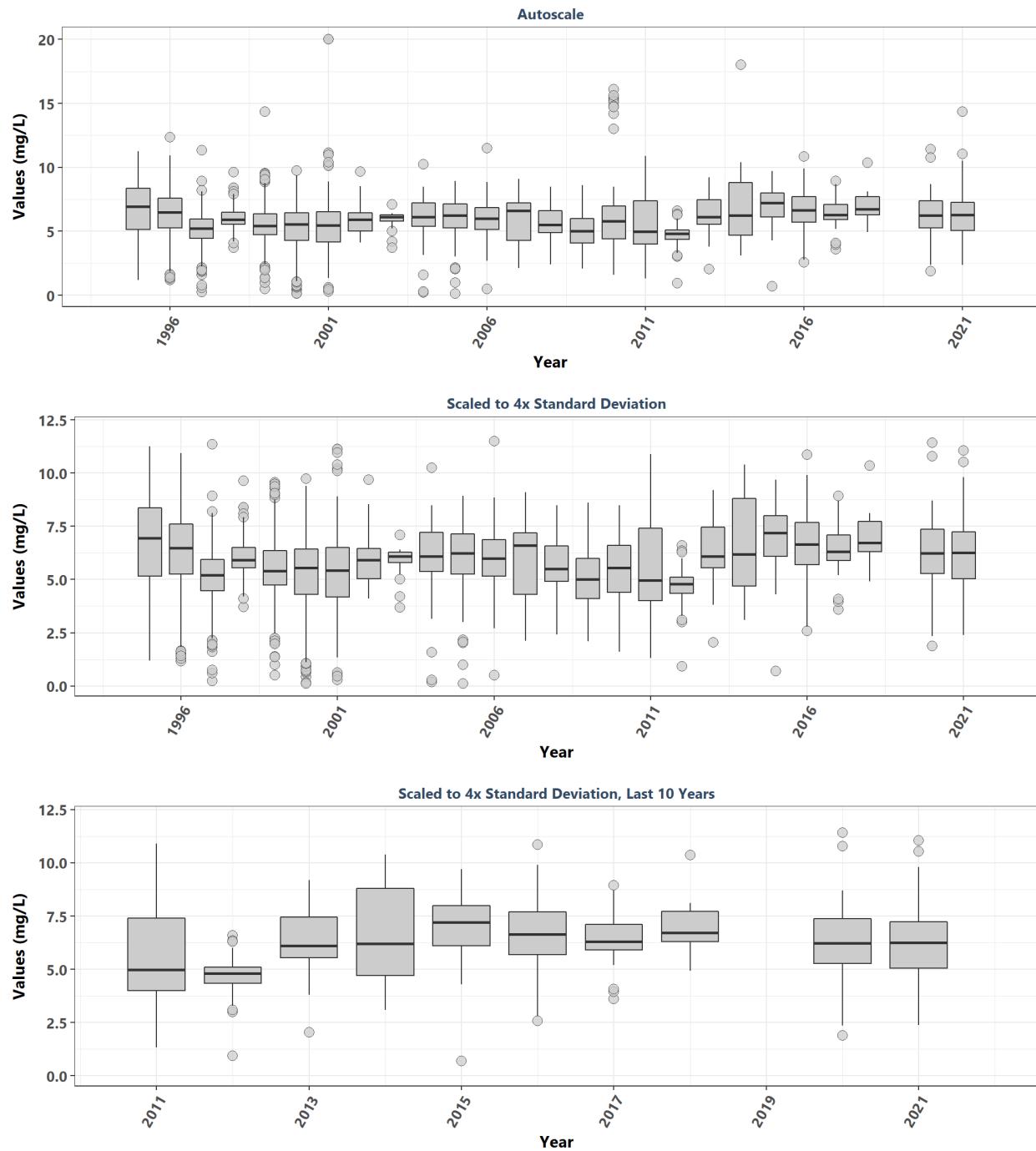
Biscayne Bay Aquatic Preserve
By Year & Month



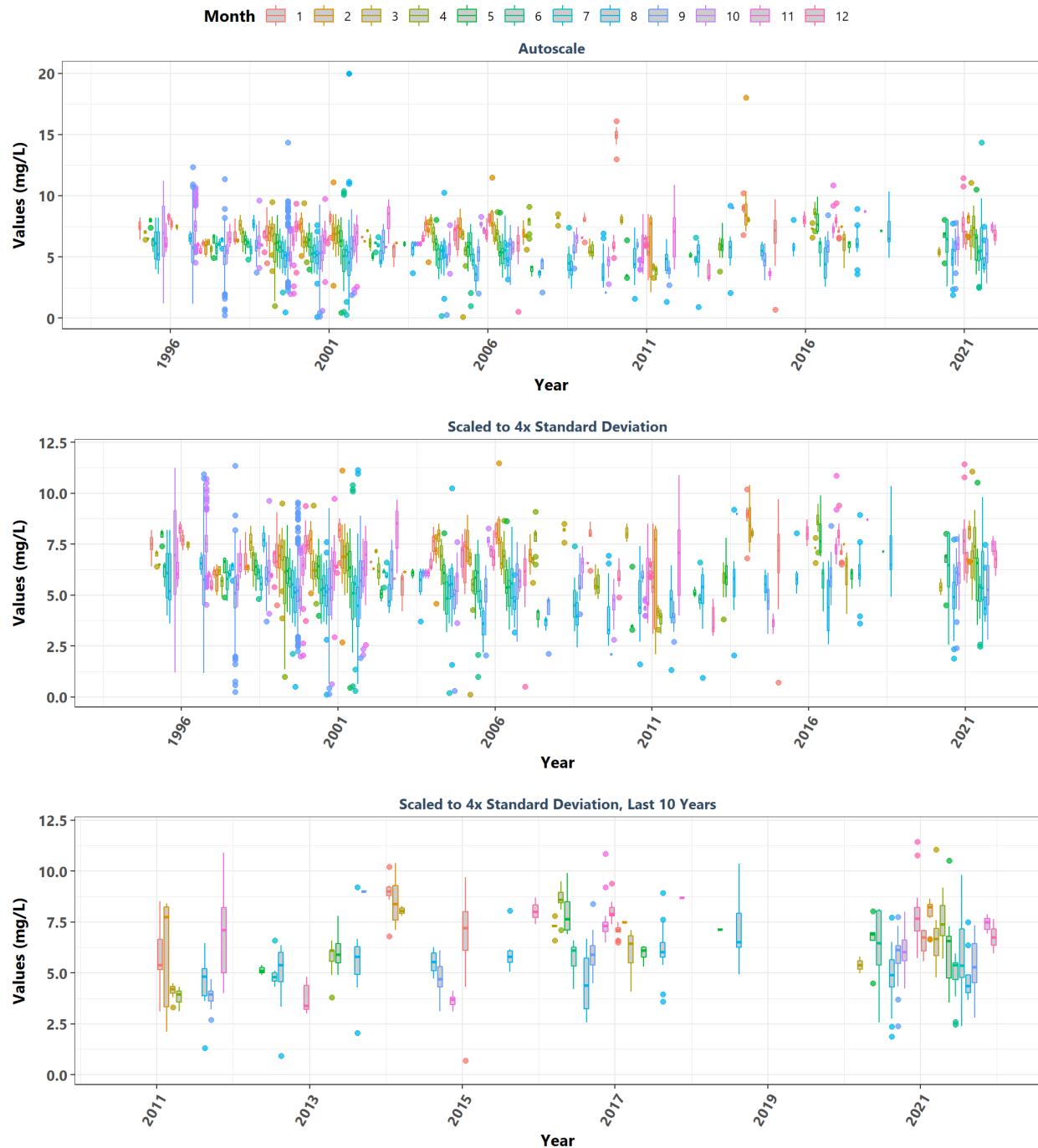
Biscayne Bay Aquatic Preserve
By Month



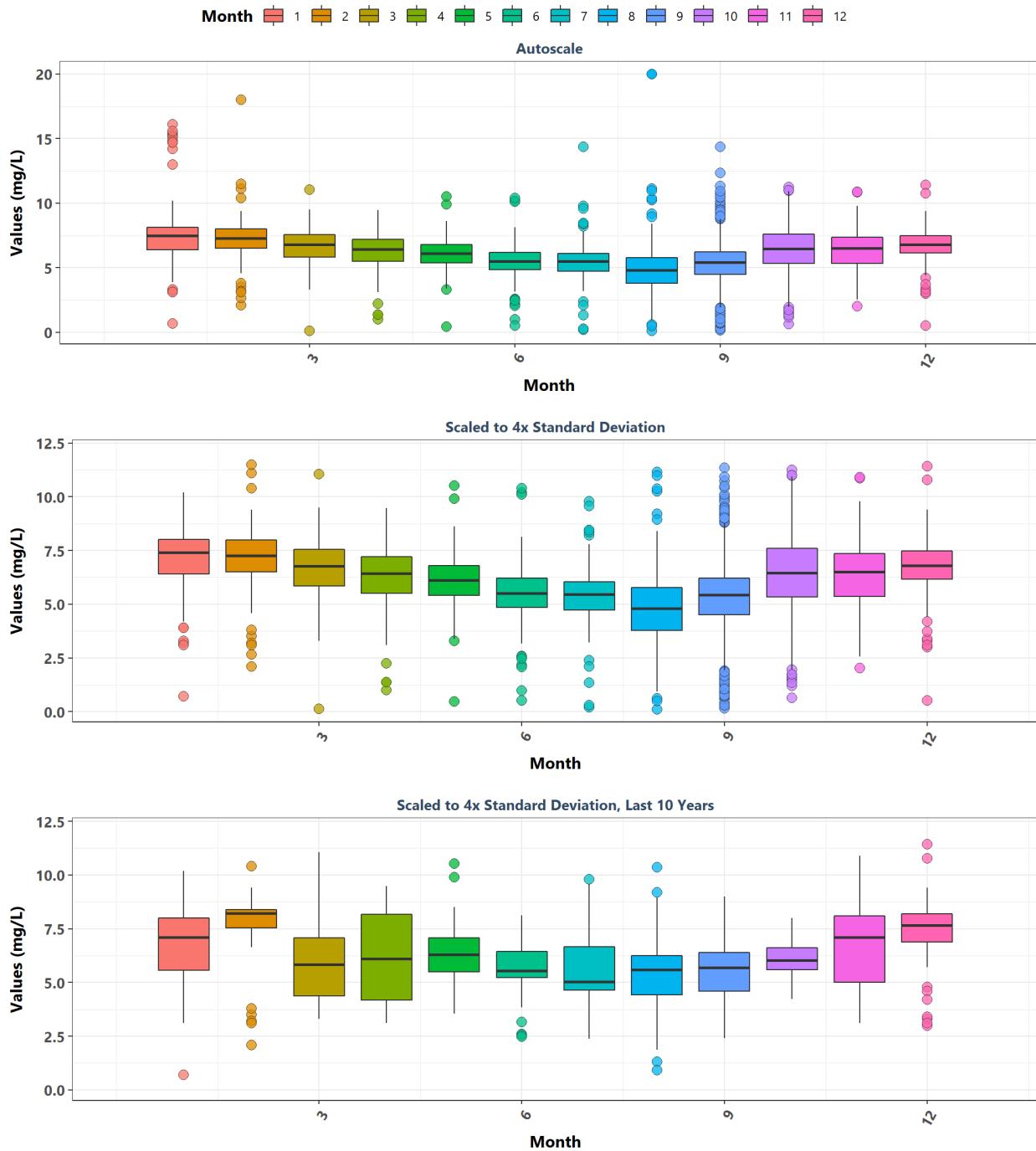
Boca Ciega Bay Aquatic Preserve
By Year



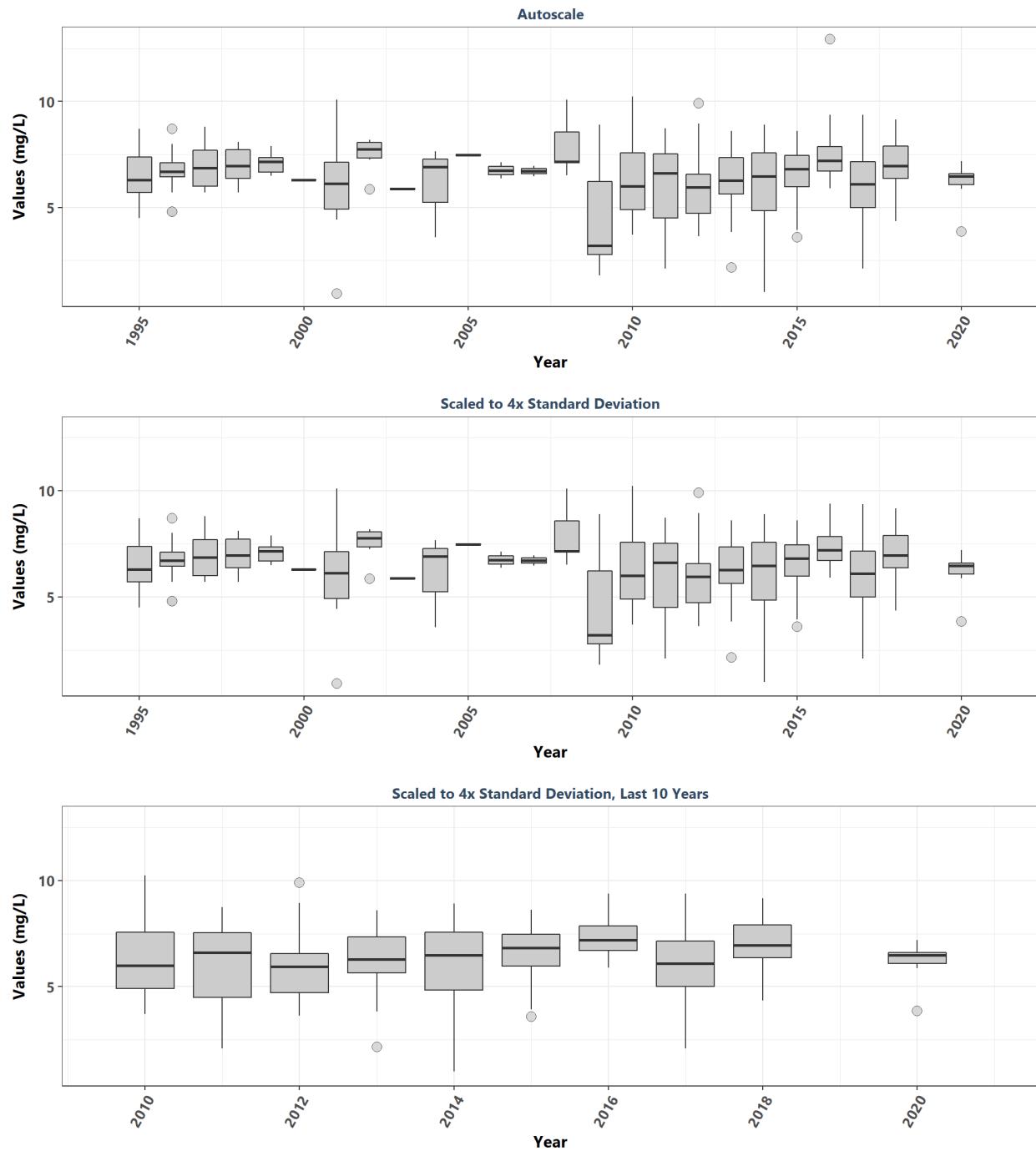
Boca Ciega Bay Aquatic Preserve
By Year & Month



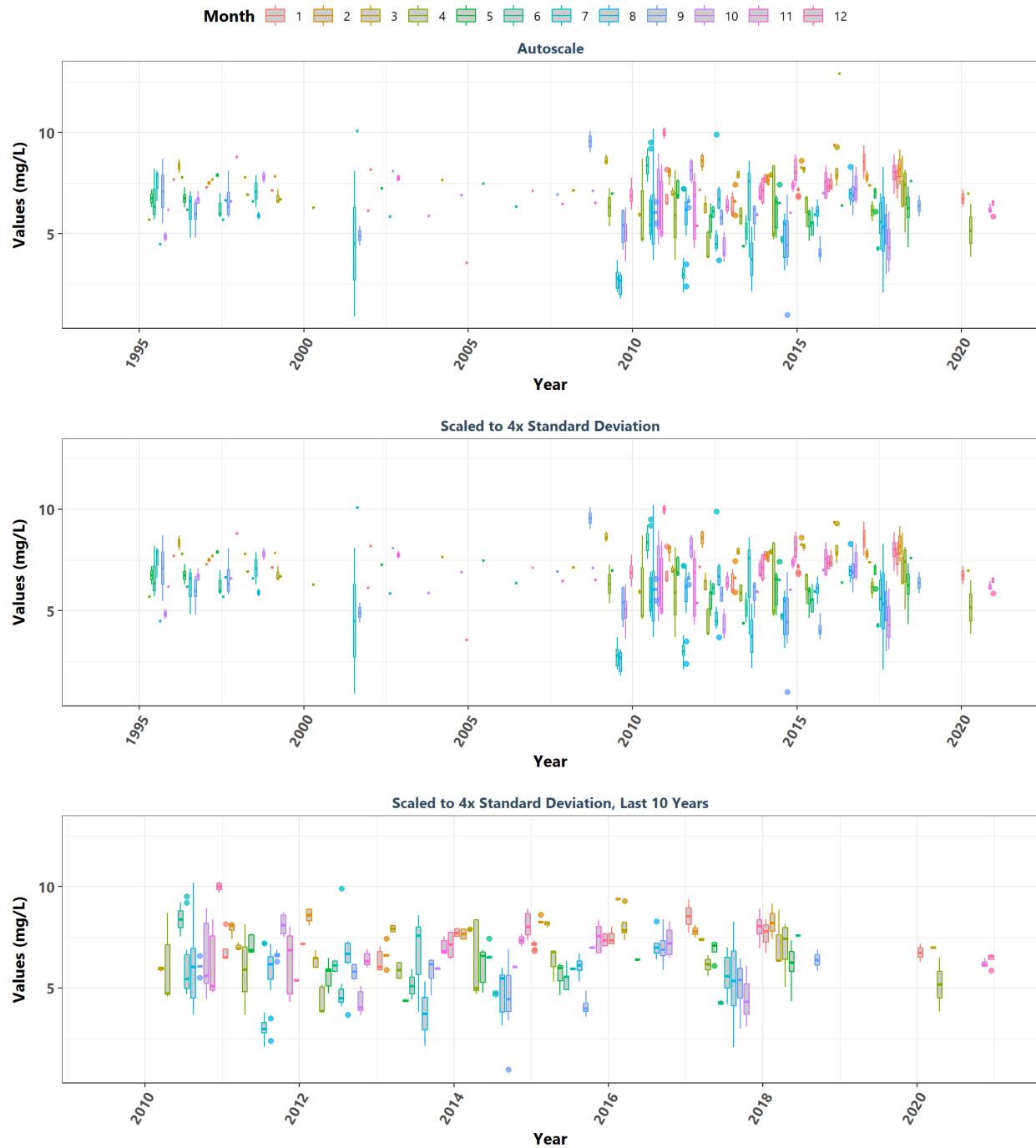
Boca Ciega Bay Aquatic Preserve
By Month



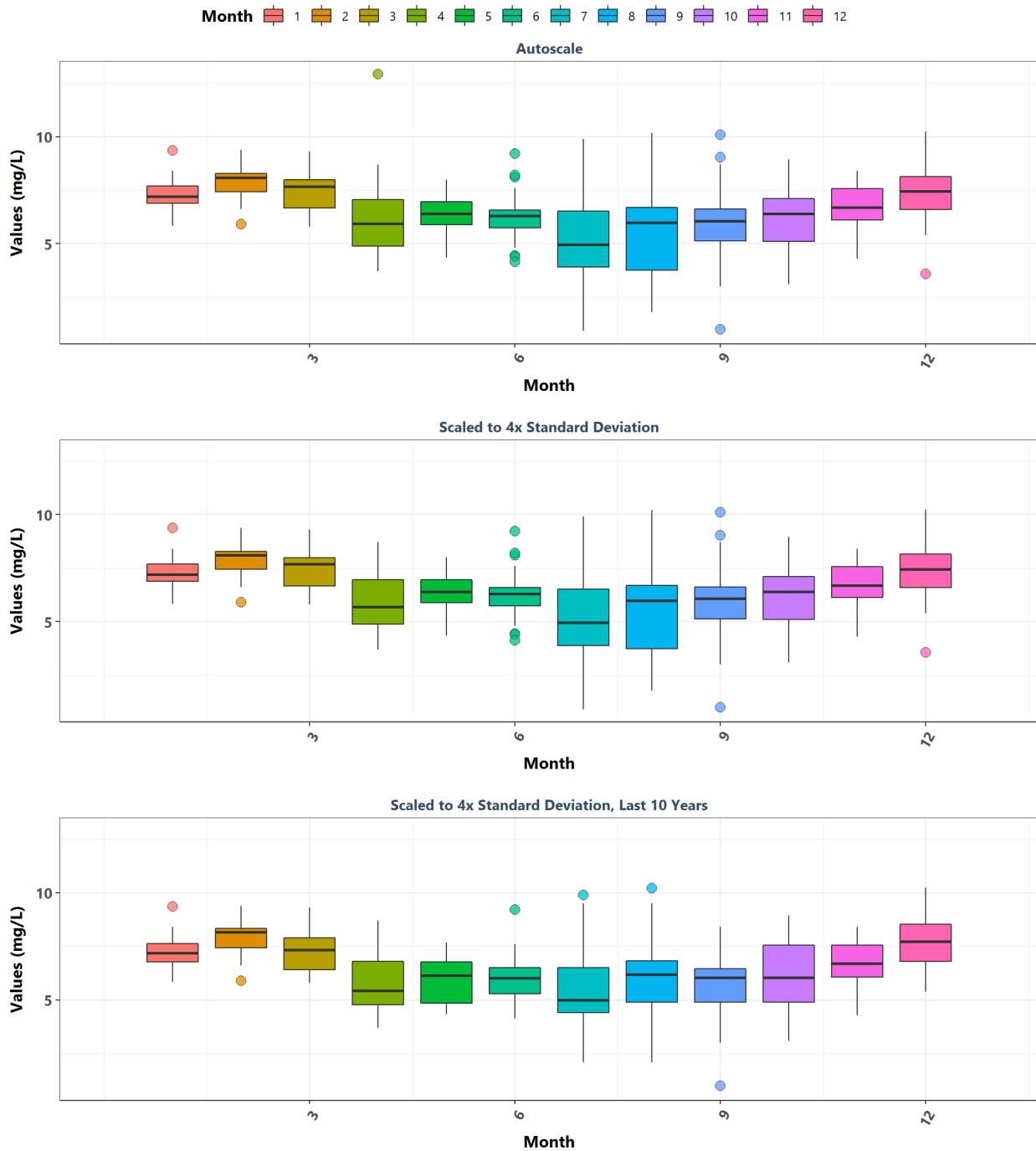
Cape Haze Aquatic Preserve
By Year



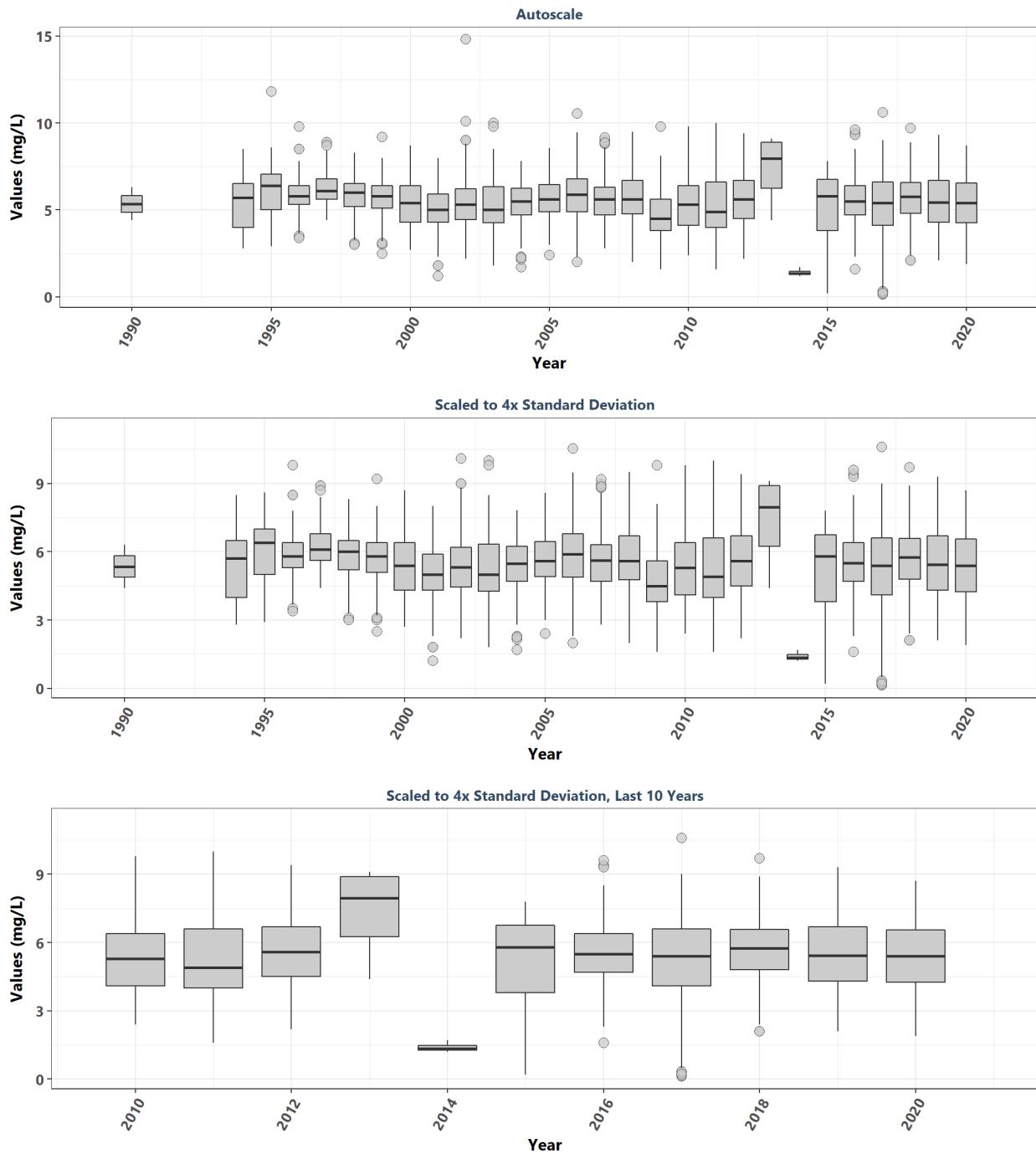
Cape Haze Aquatic Preserve
By Year & Month



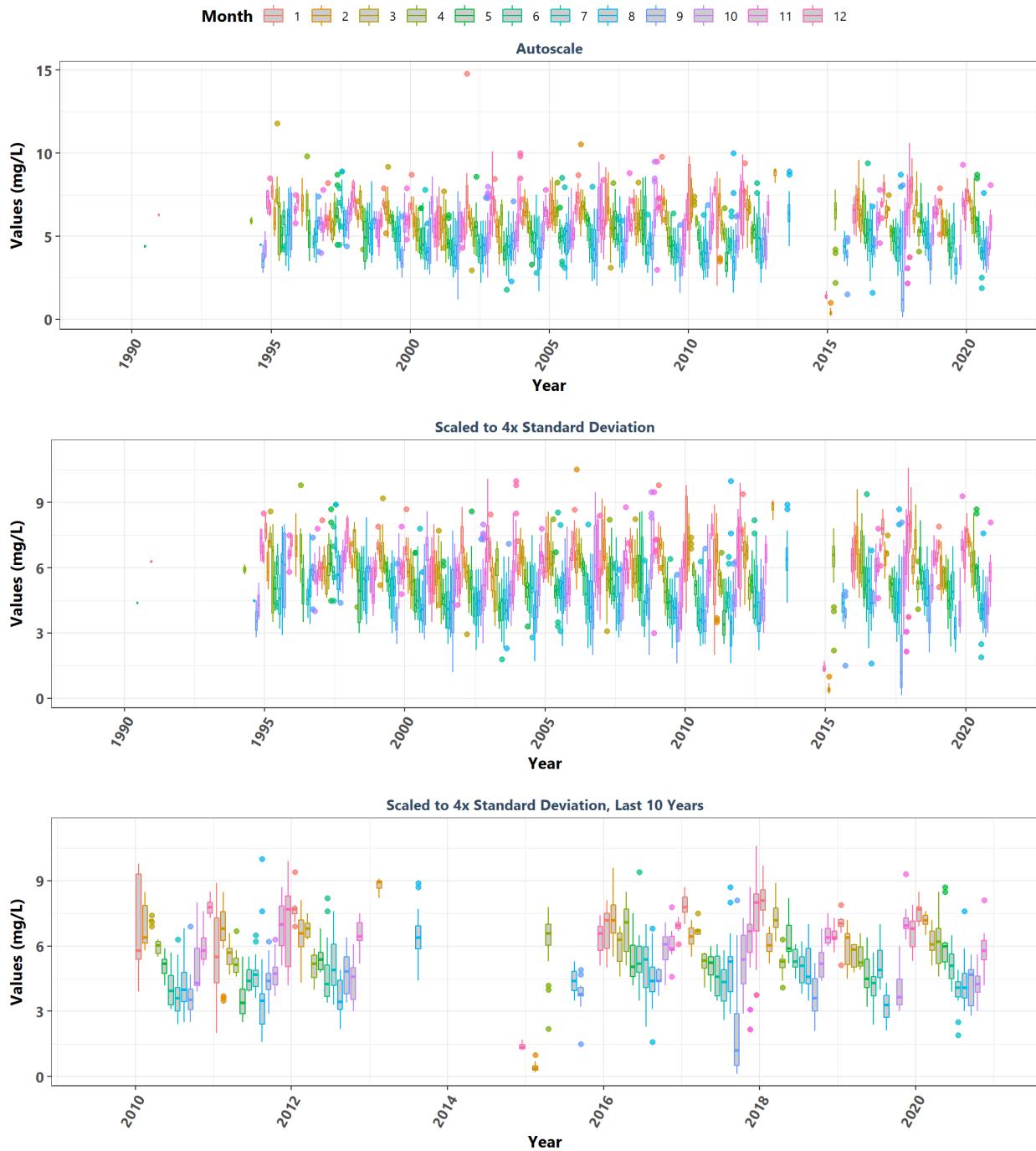
Cape Haze Aquatic Preserve
By Month



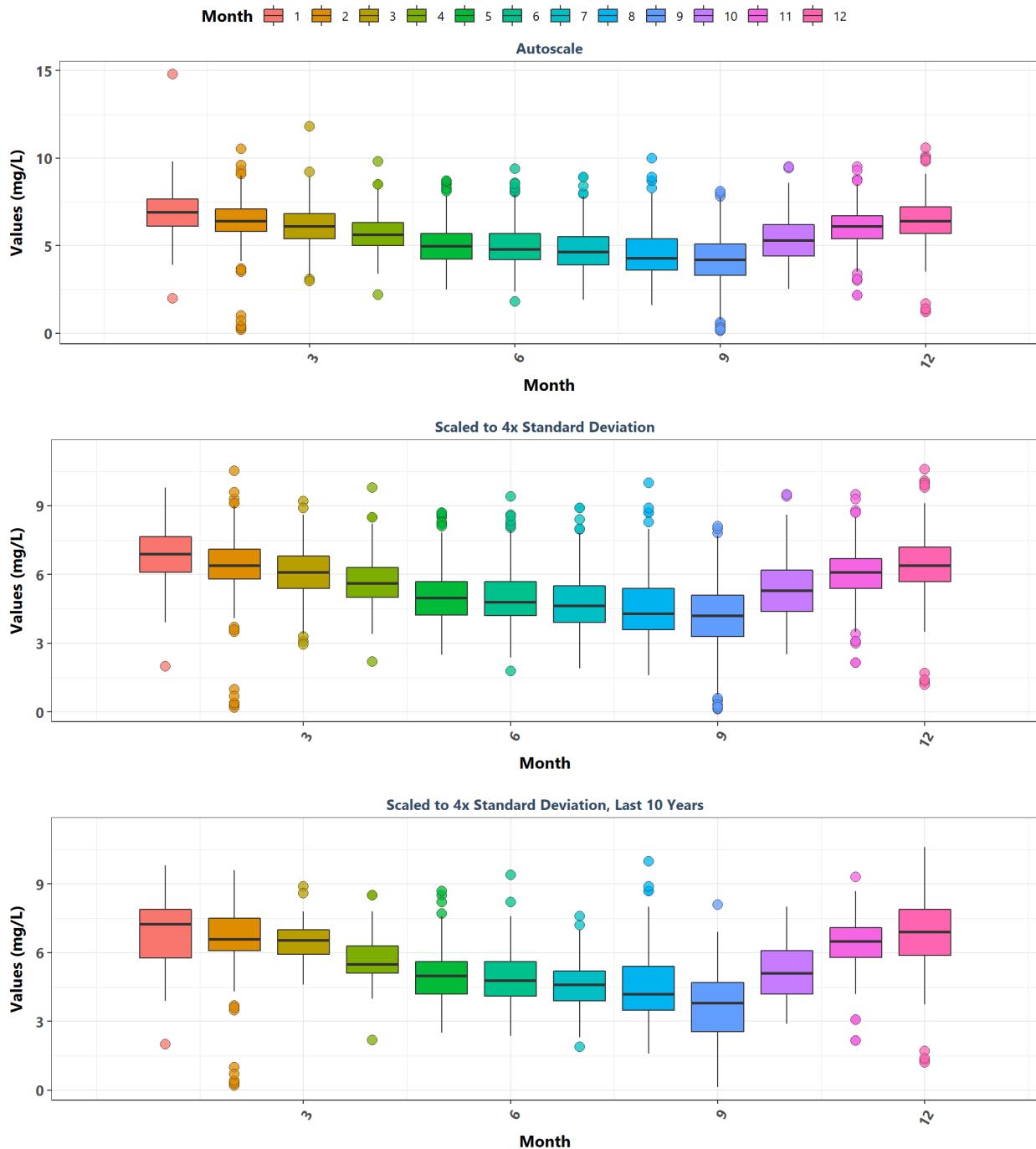
Cape Romano-Ten Thousand Islands Aquatic Preserve
By Year



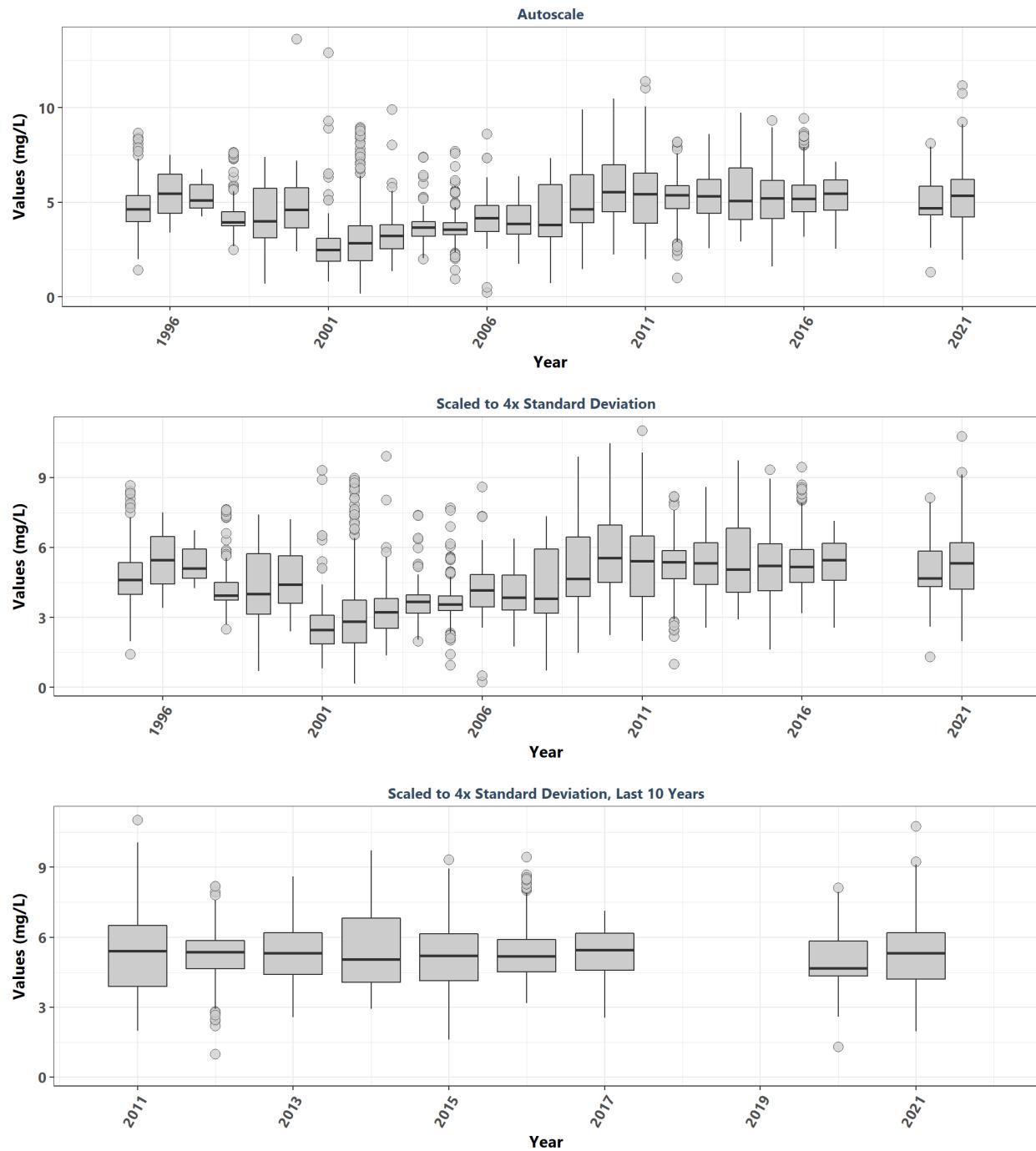
Cape Romano-Ten Thousand Islands Aquatic Preserve
By Year & Month



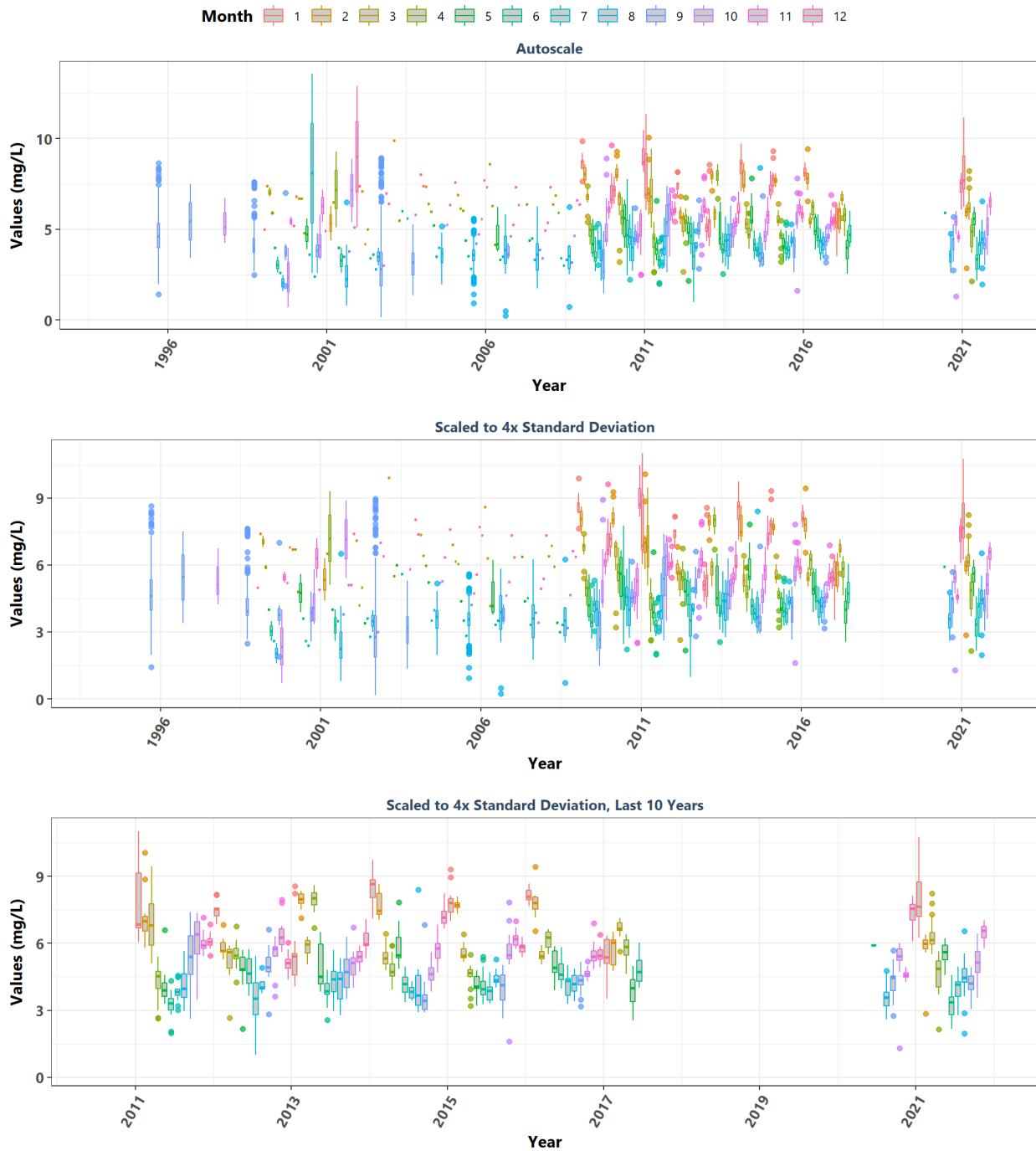
Cape Romano-Ten Thousand Islands Aquatic Preserve
By Month



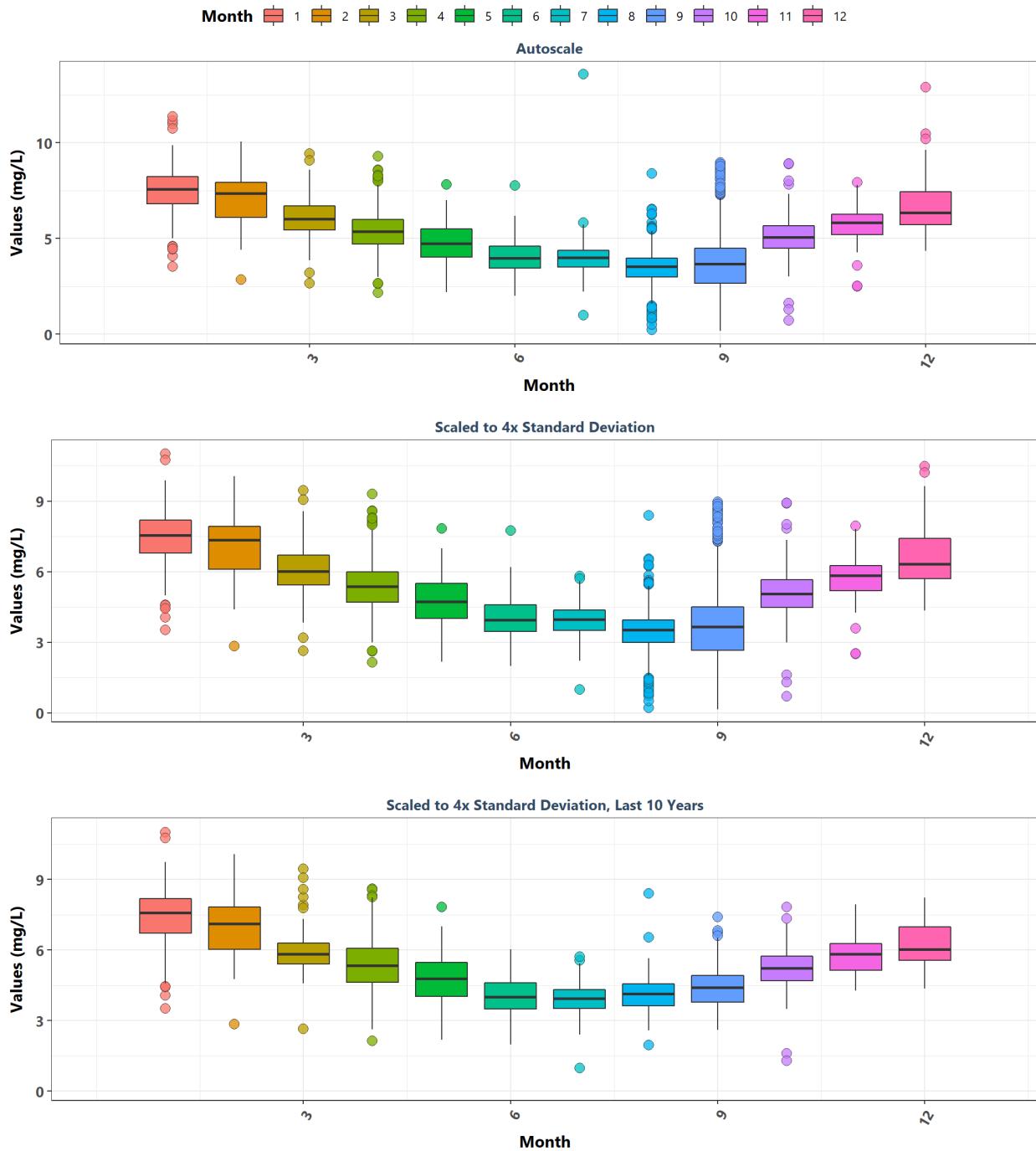
Cockroach Bay Aquatic Preserve
By Year



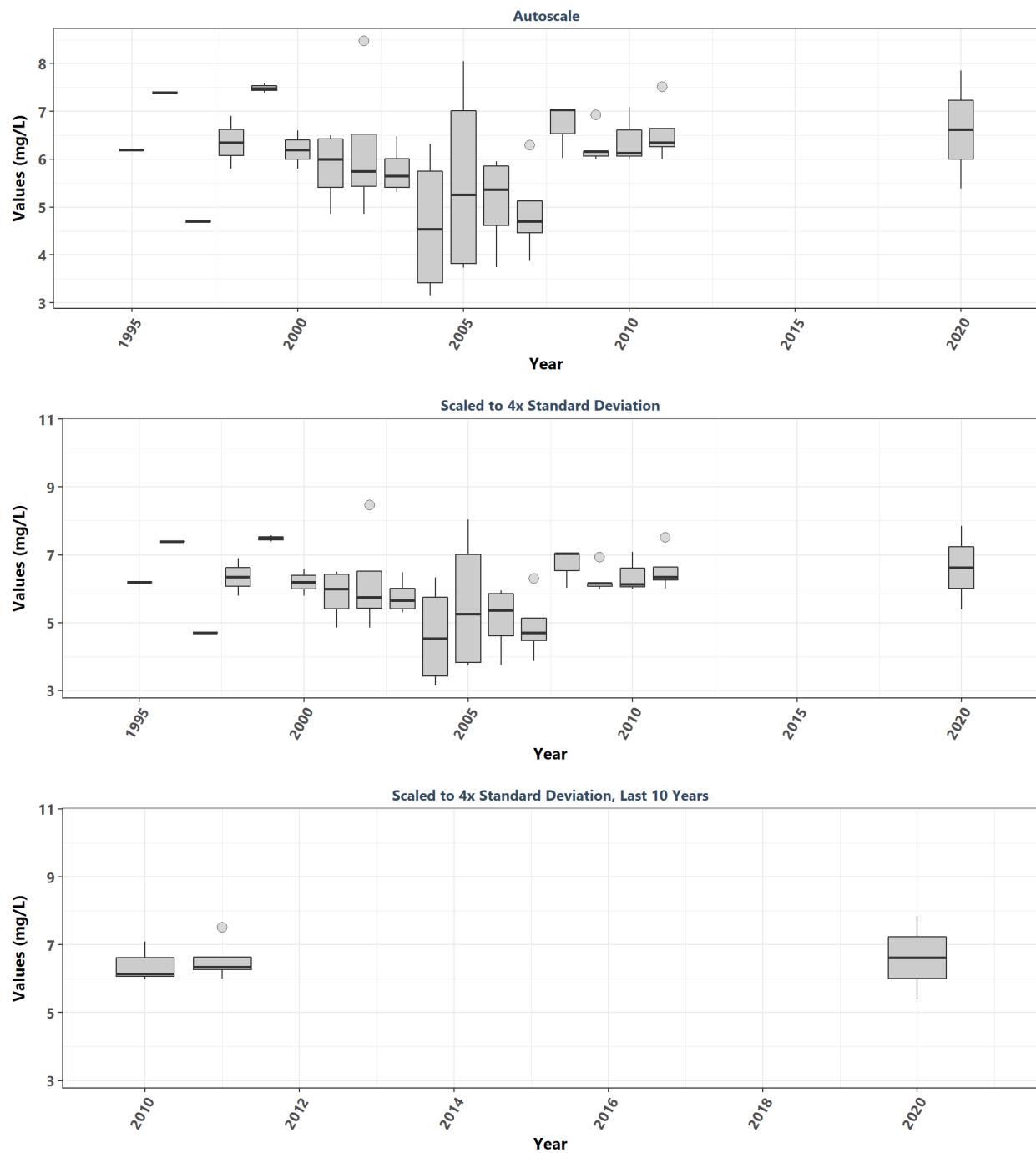
Cockroach Bay Aquatic Preserve
By Year & Month



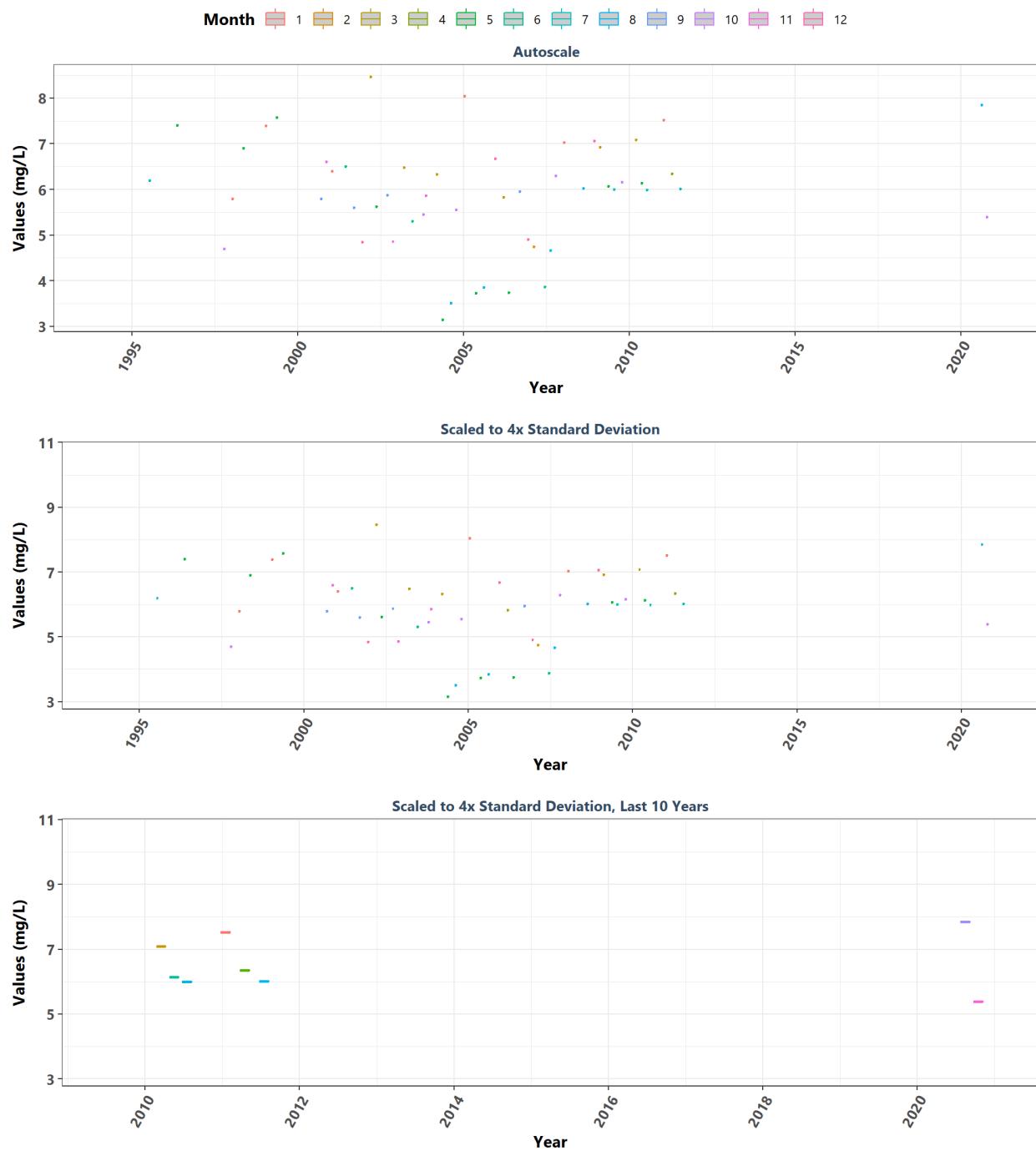
Cockroach Bay Aquatic Preserve
By Month



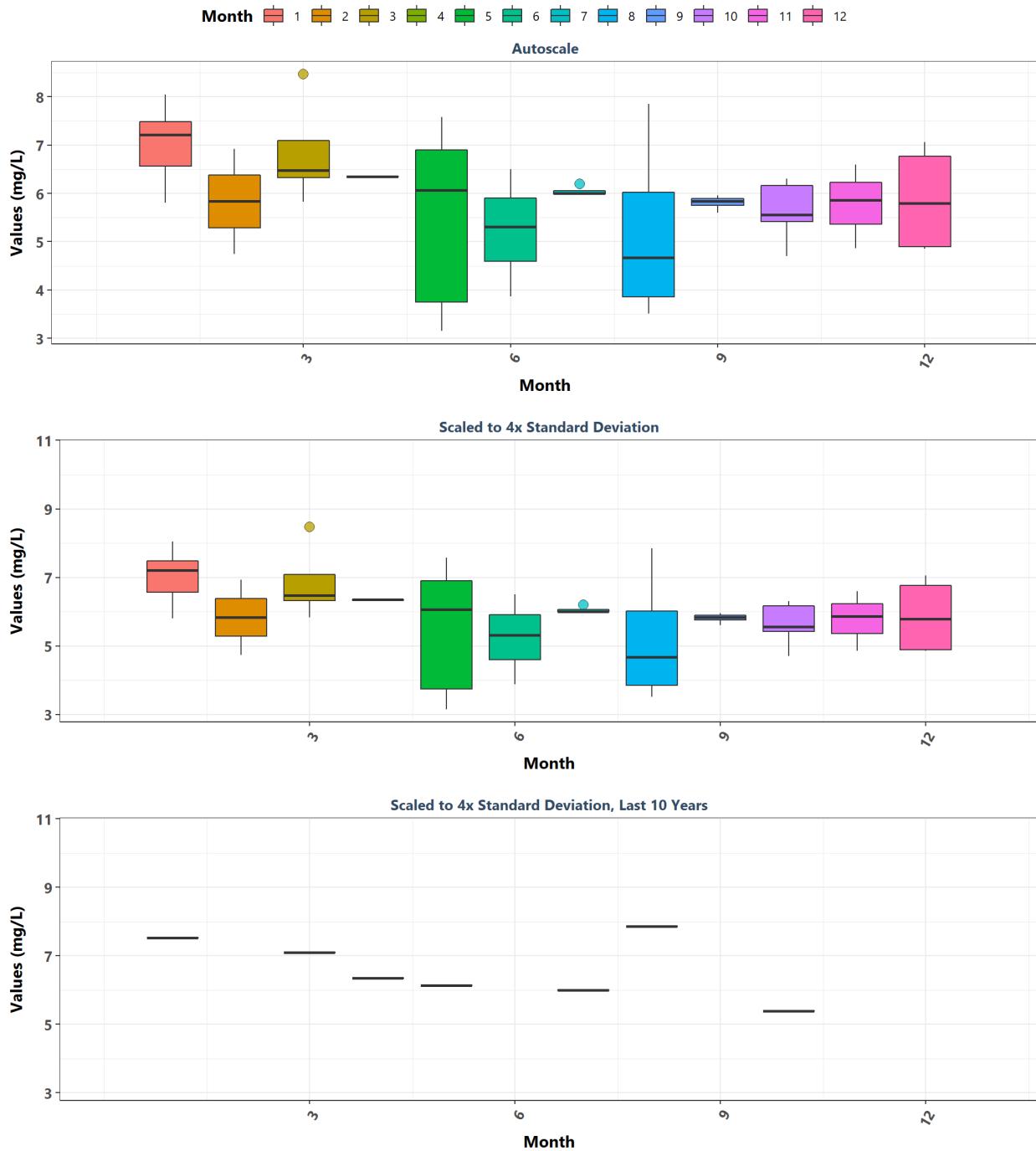
Coupon Bight Aquatic Preserve
By Year



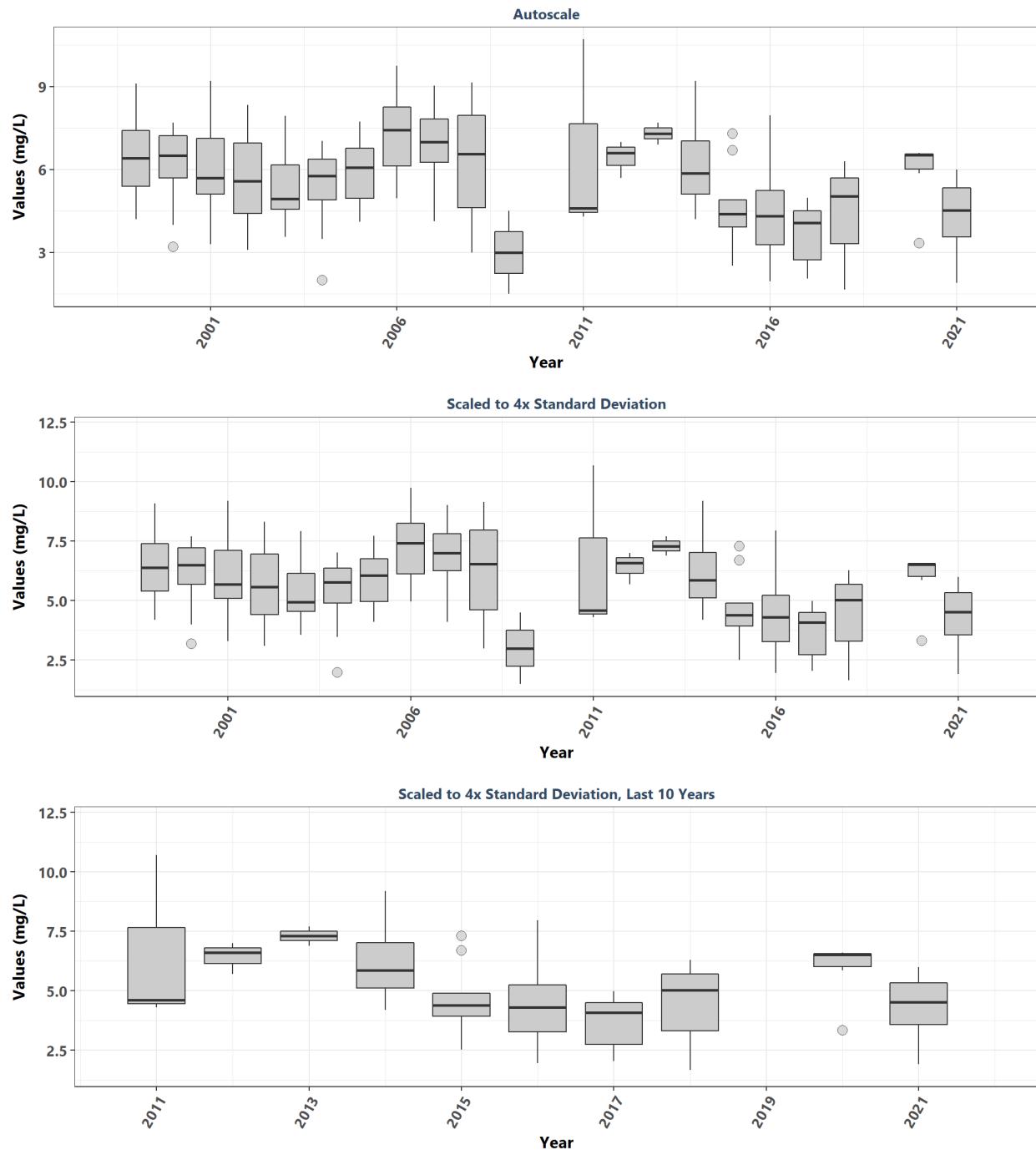
Coupon Eight Aquatic Preserve
By Year & Month



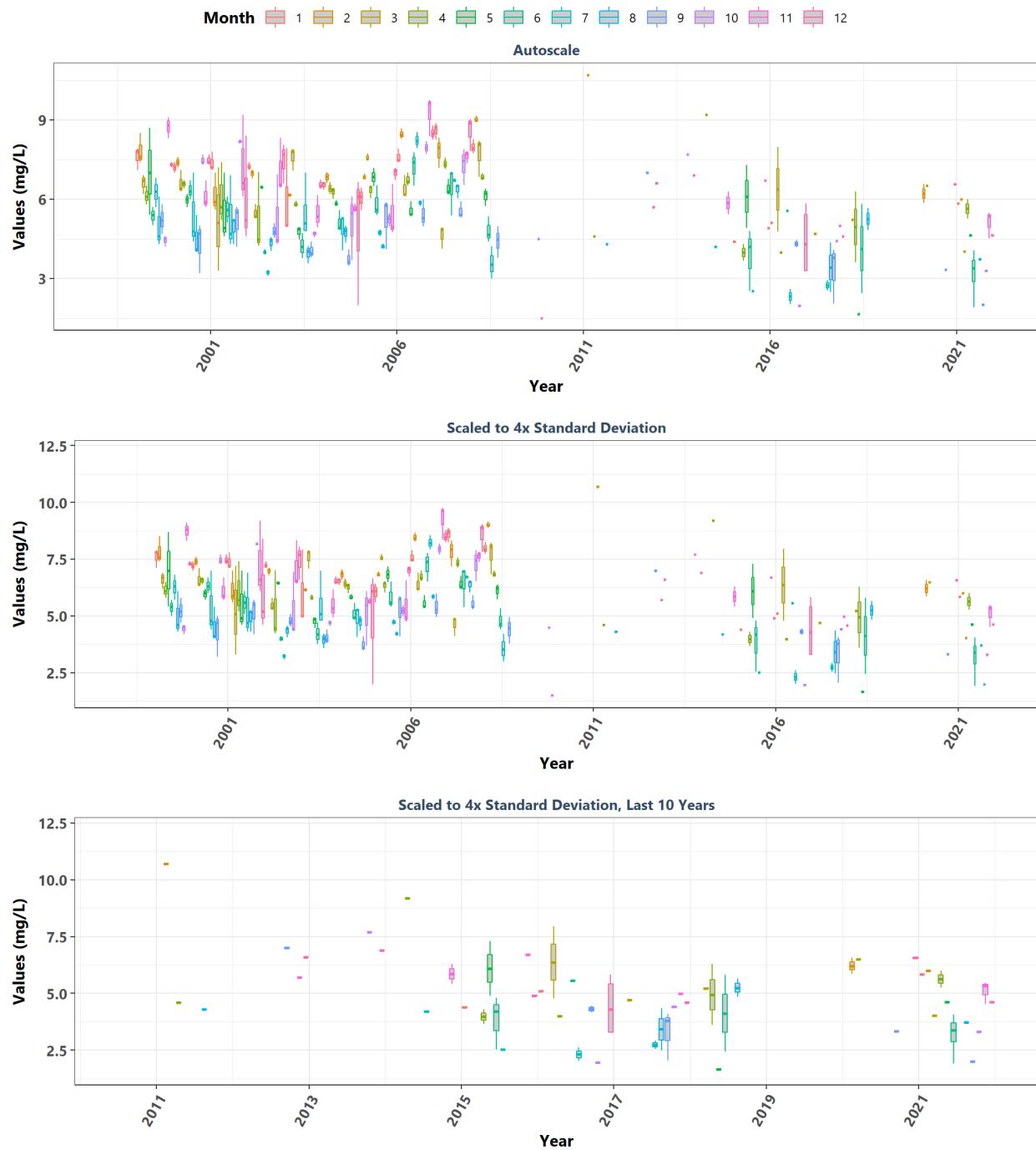
Coupon Eight Aquatic Preserve
By Month



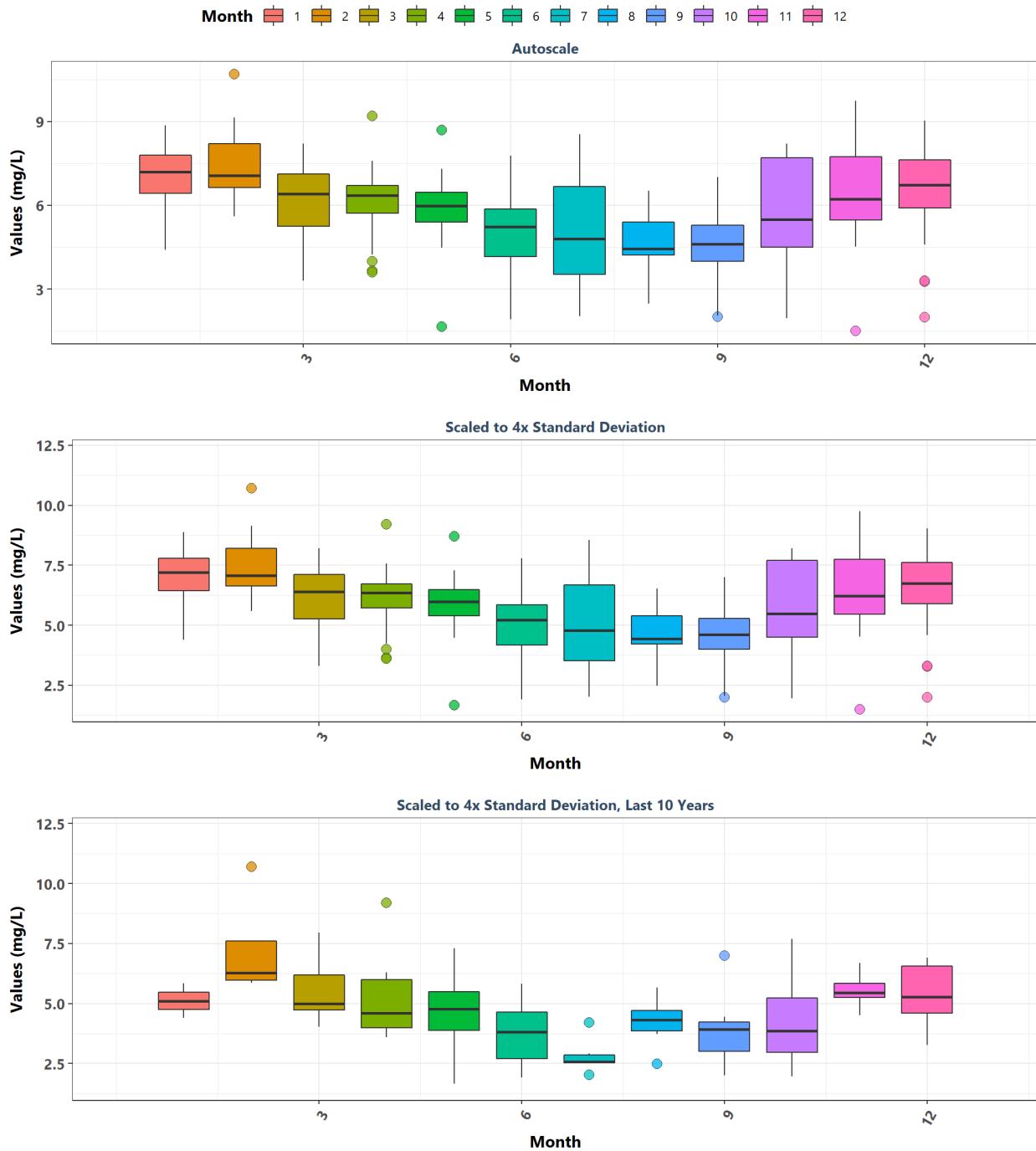
Estero Bay Aquatic Preserve
By Year



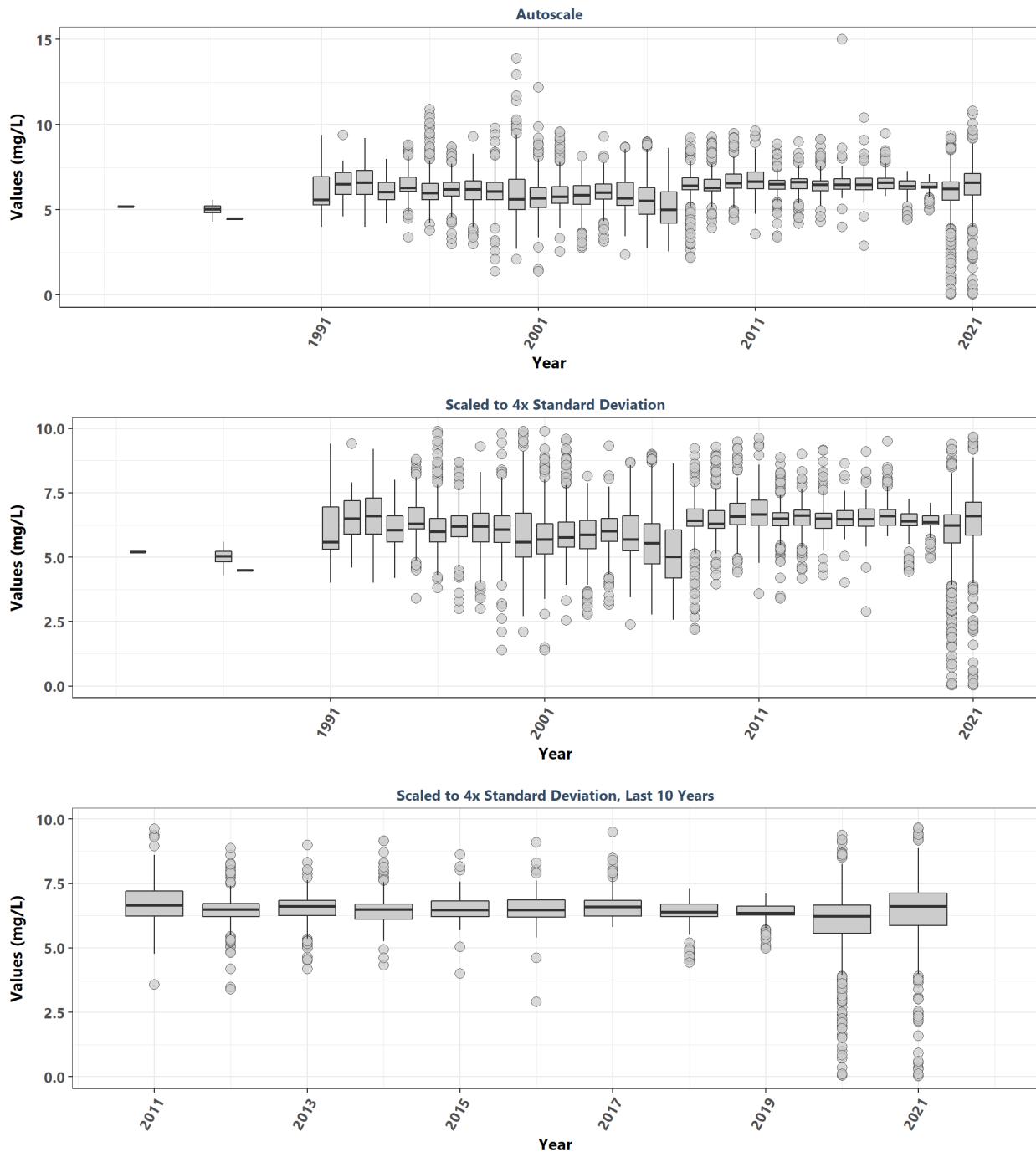
Estero Bay Aquatic Preserve
By Year & Month



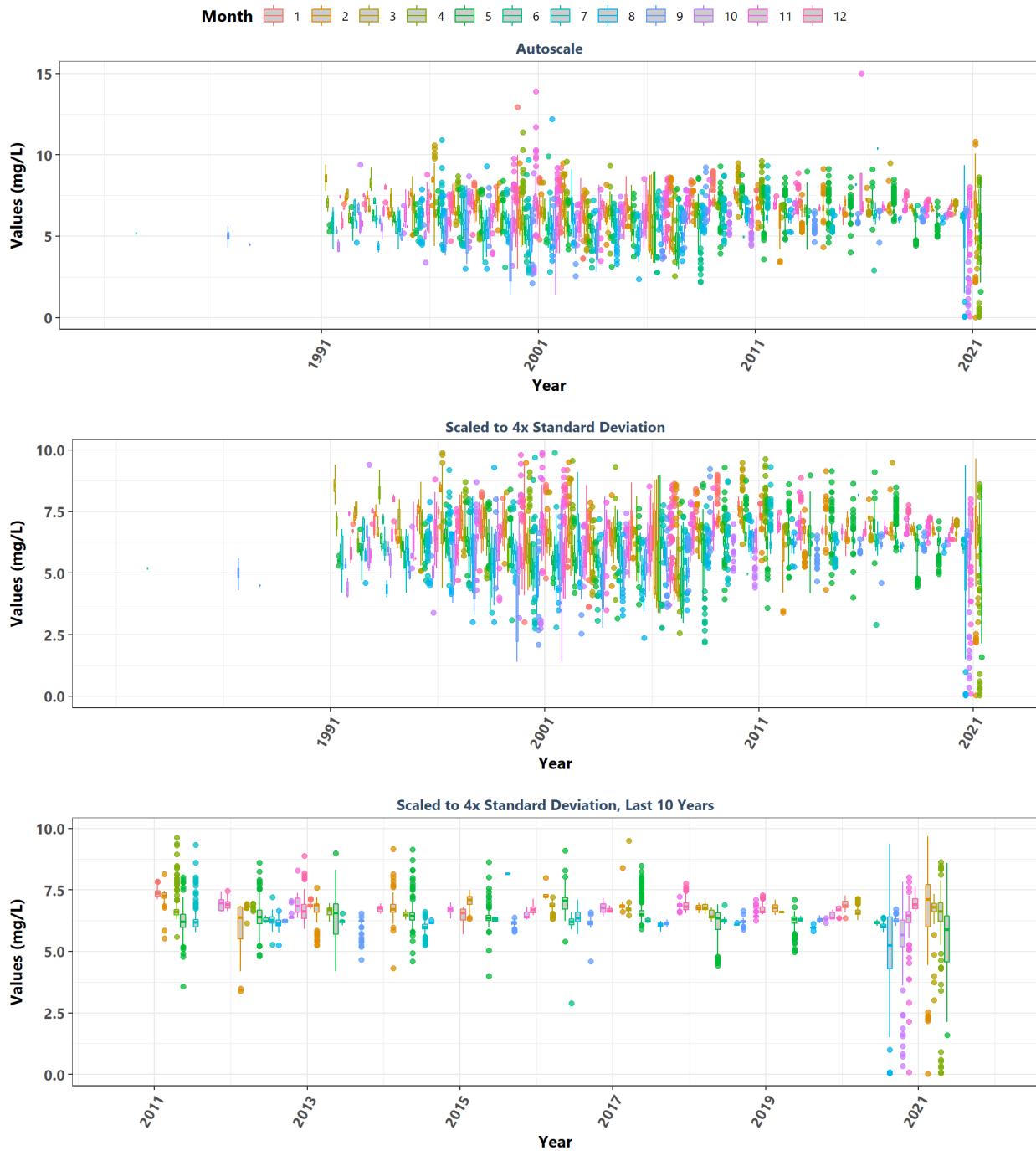
Estero Bay Aquatic Preserve
By Month



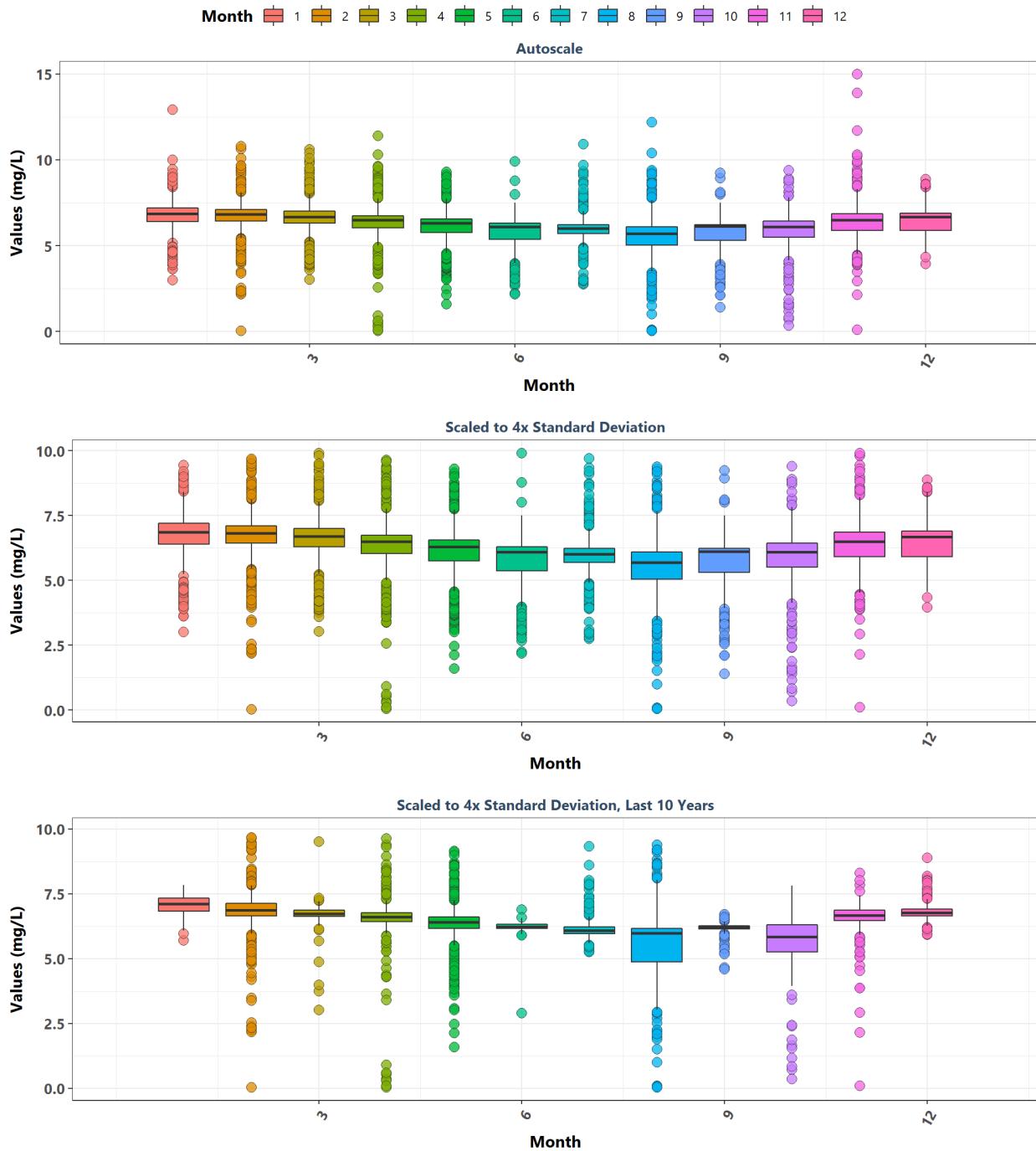
Florida Keys National Marine Sanctuary
By Year



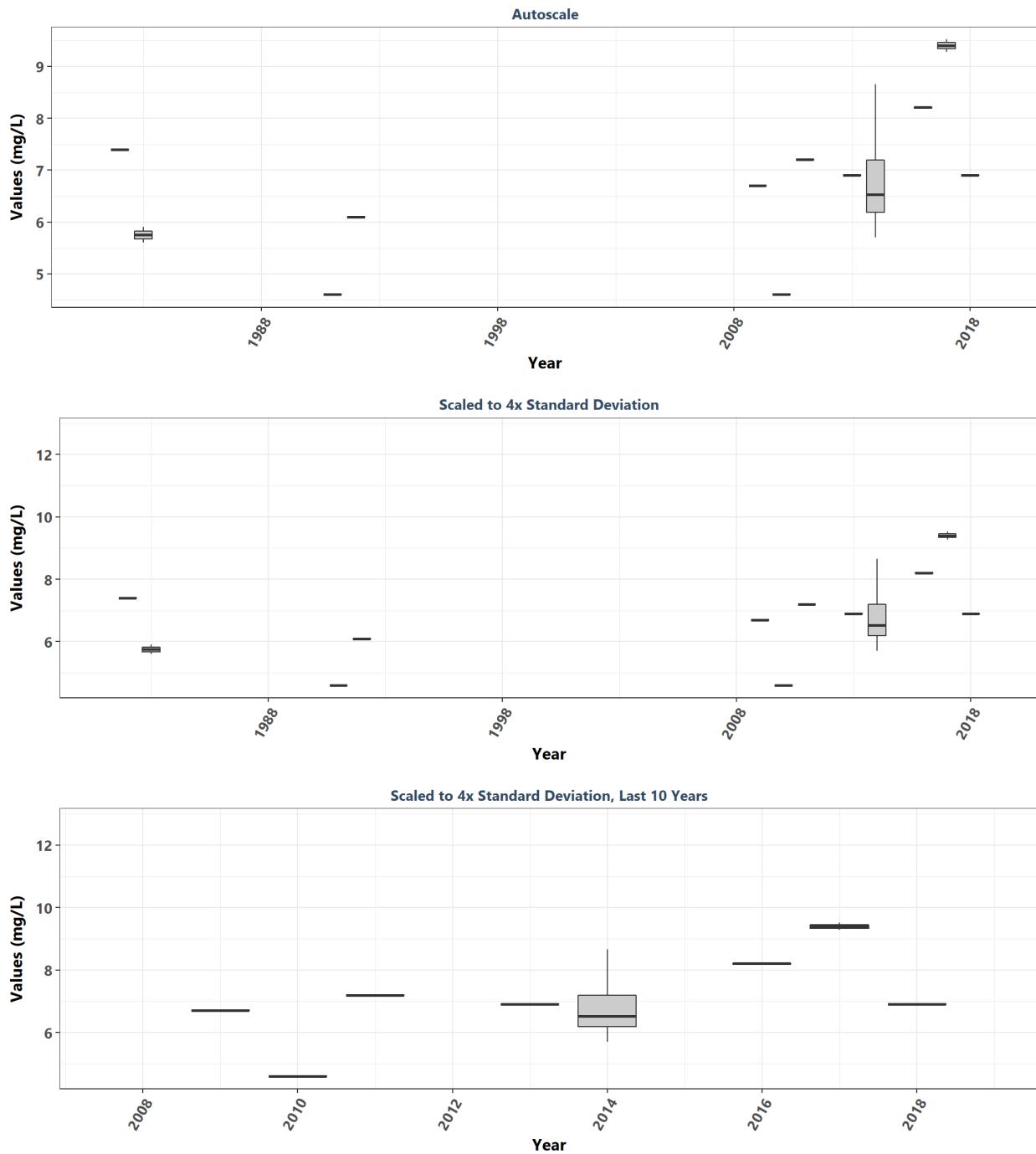
Florida Keys National Marine Sanctuary
By Year & Month



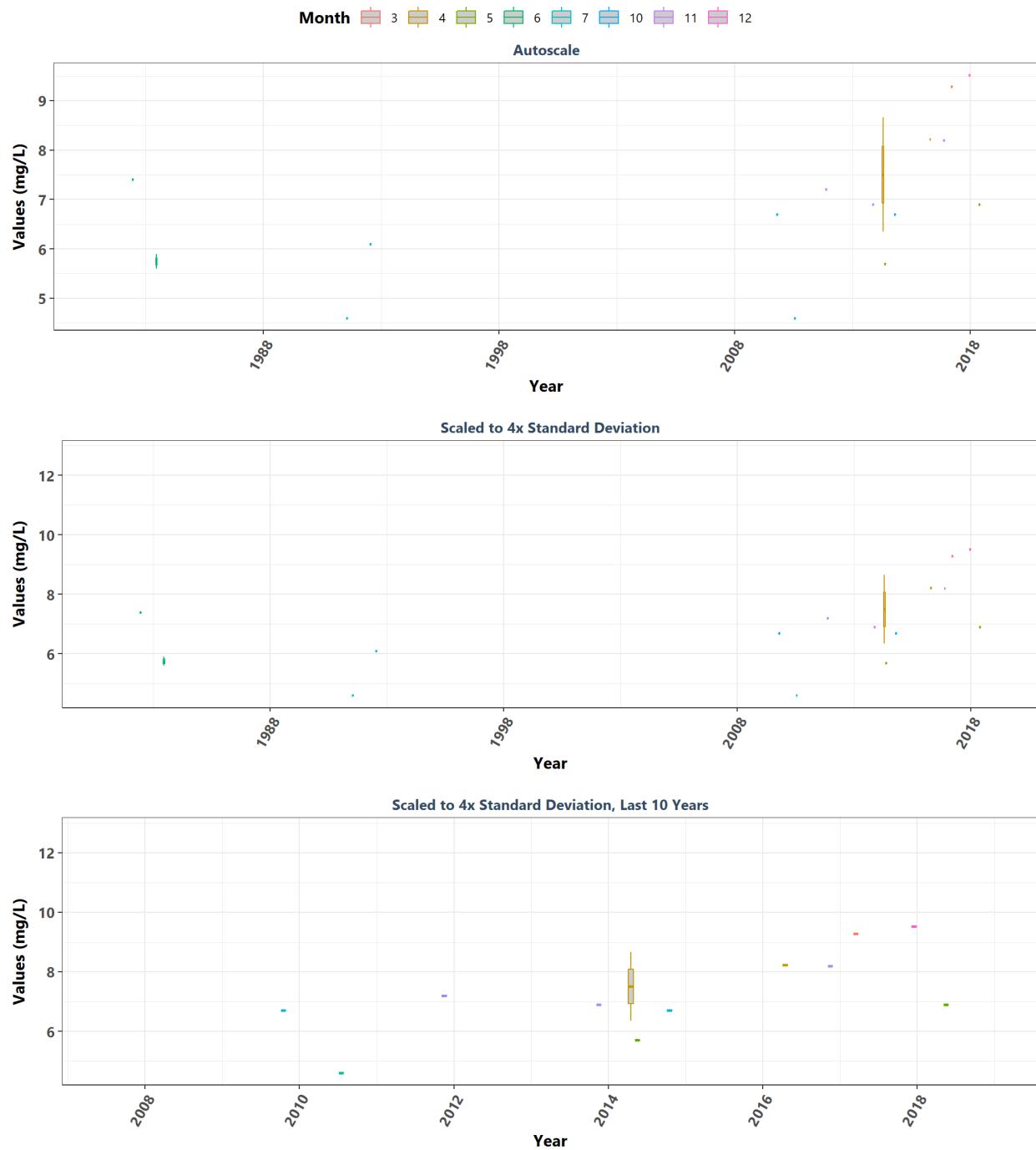
Florida Keys National Marine Sanctuary
By Month



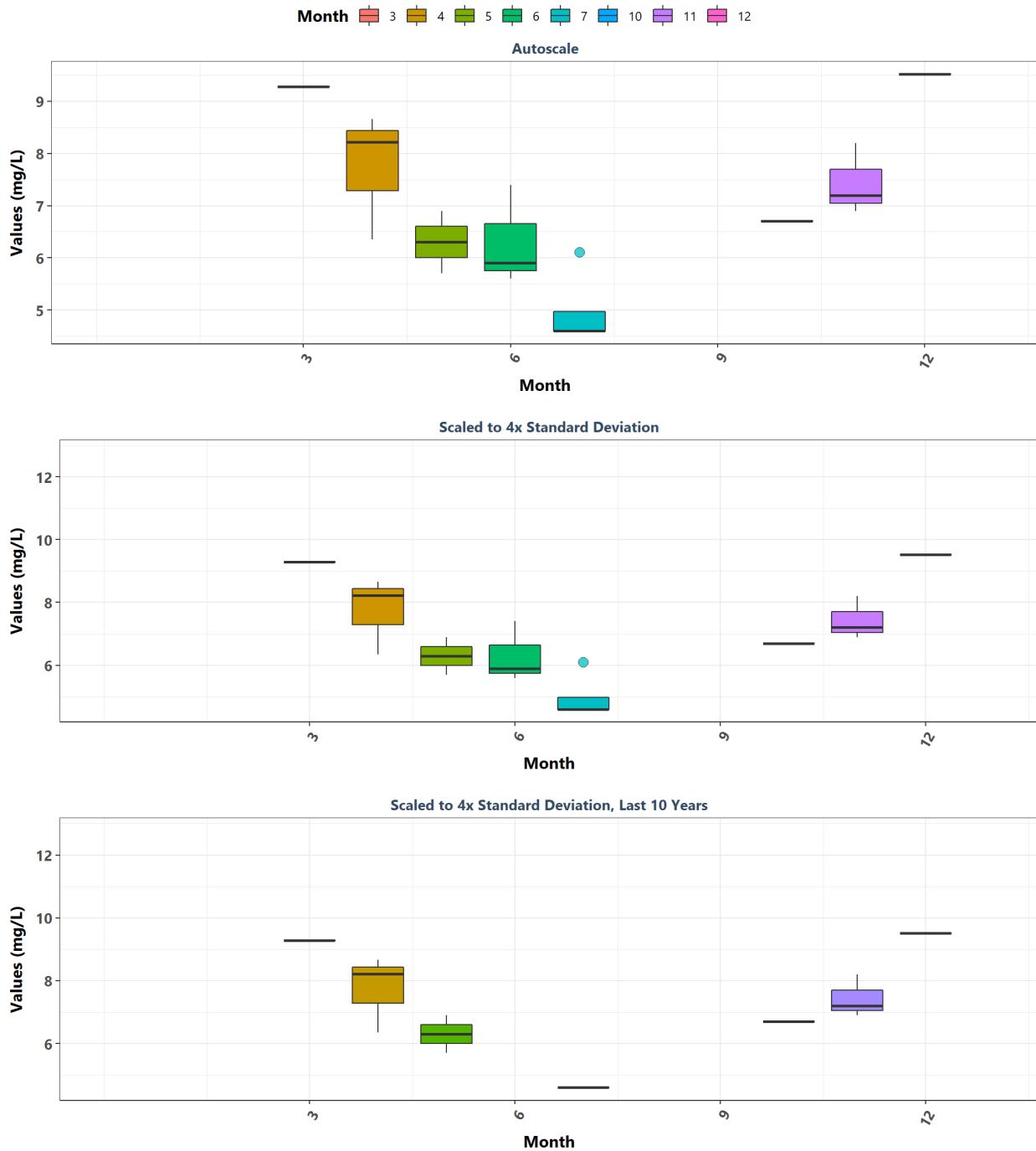
Fort Pickens State Park Aquatic Preserve
By Year



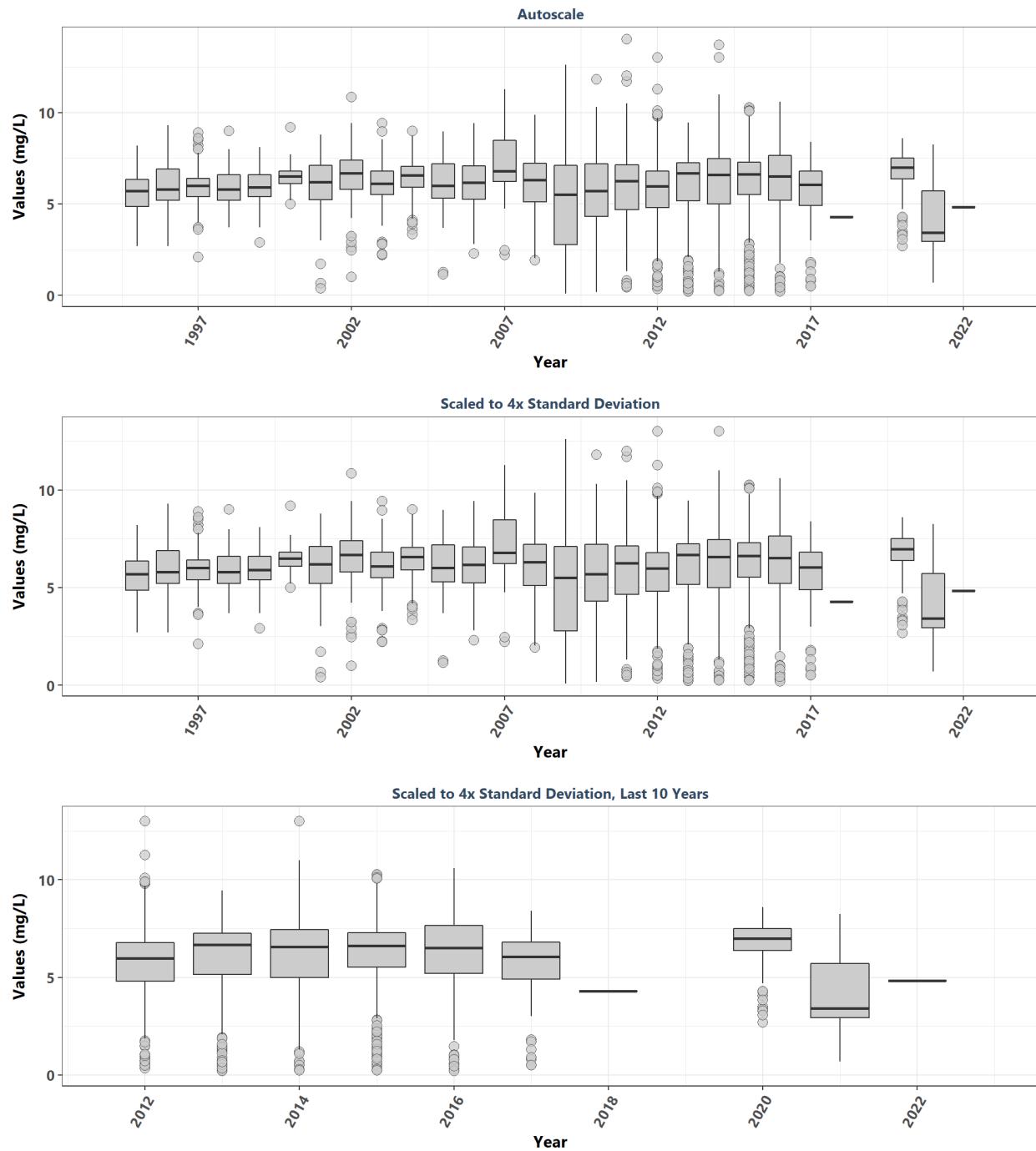
Fort Pickens State Park Aquatic Preserve
By Year & Month



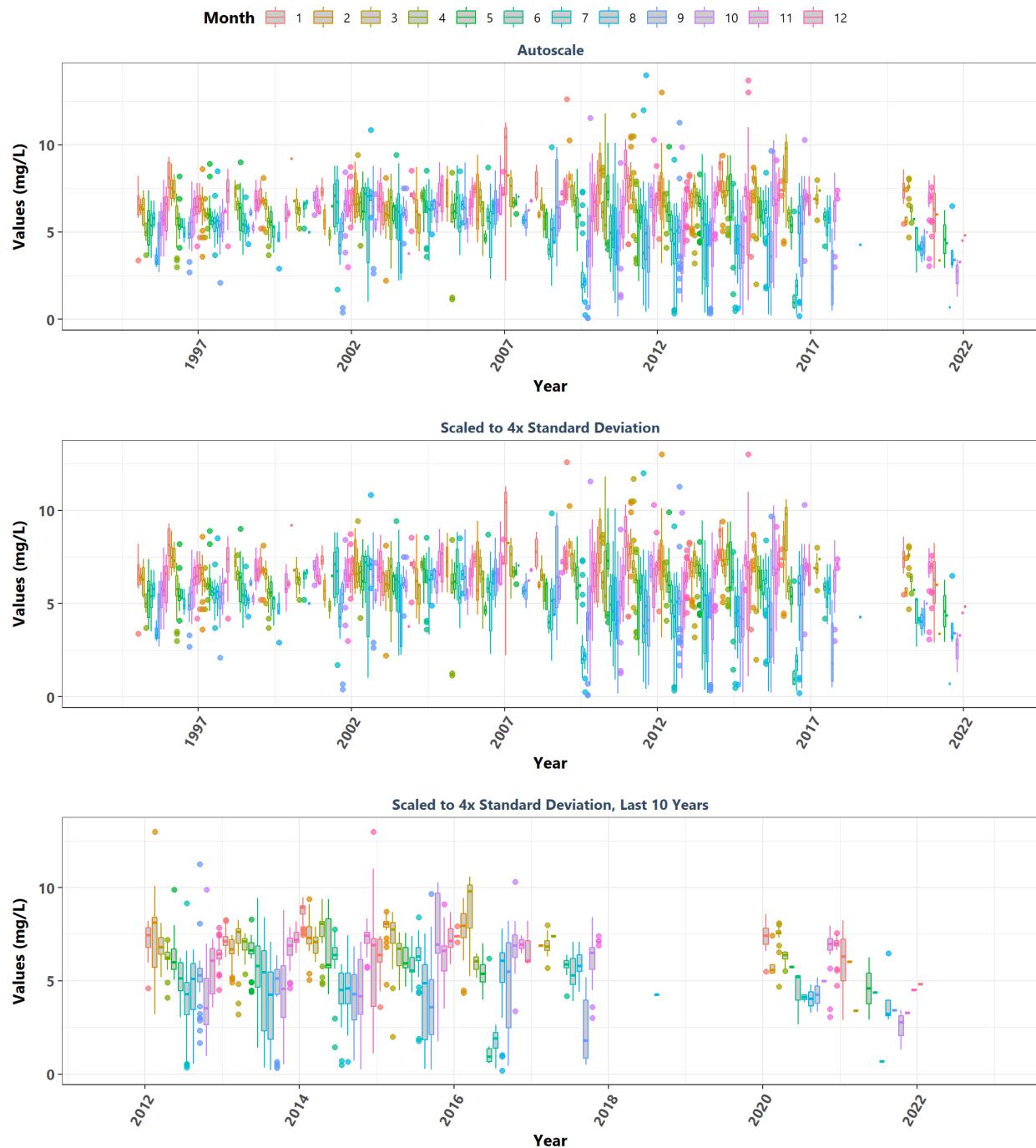
Fort Pickens State Park Aquatic Preserve
By Month



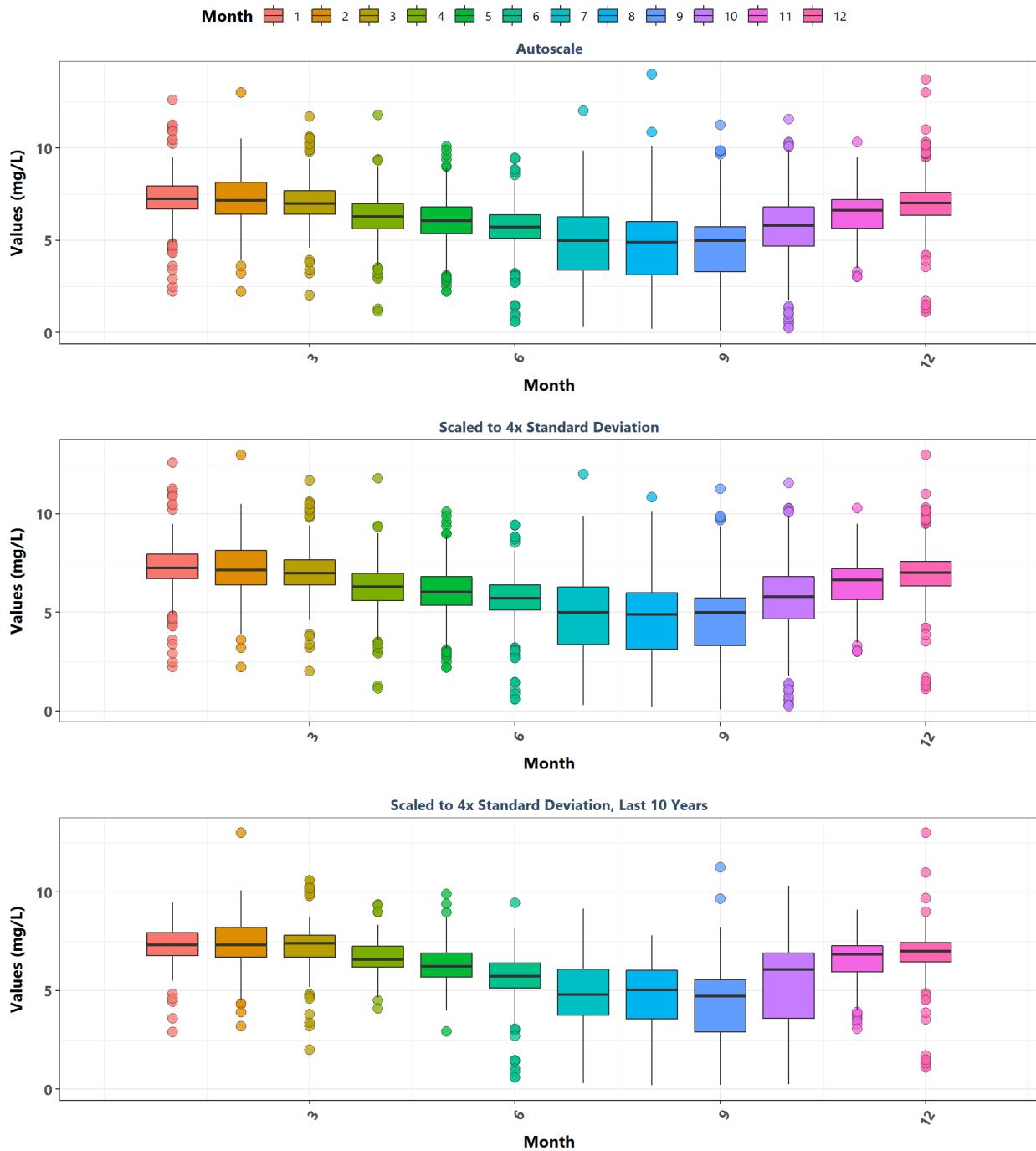
Gasparilla Sound-Charlotte Harbor Aquatic Preserve
By Year



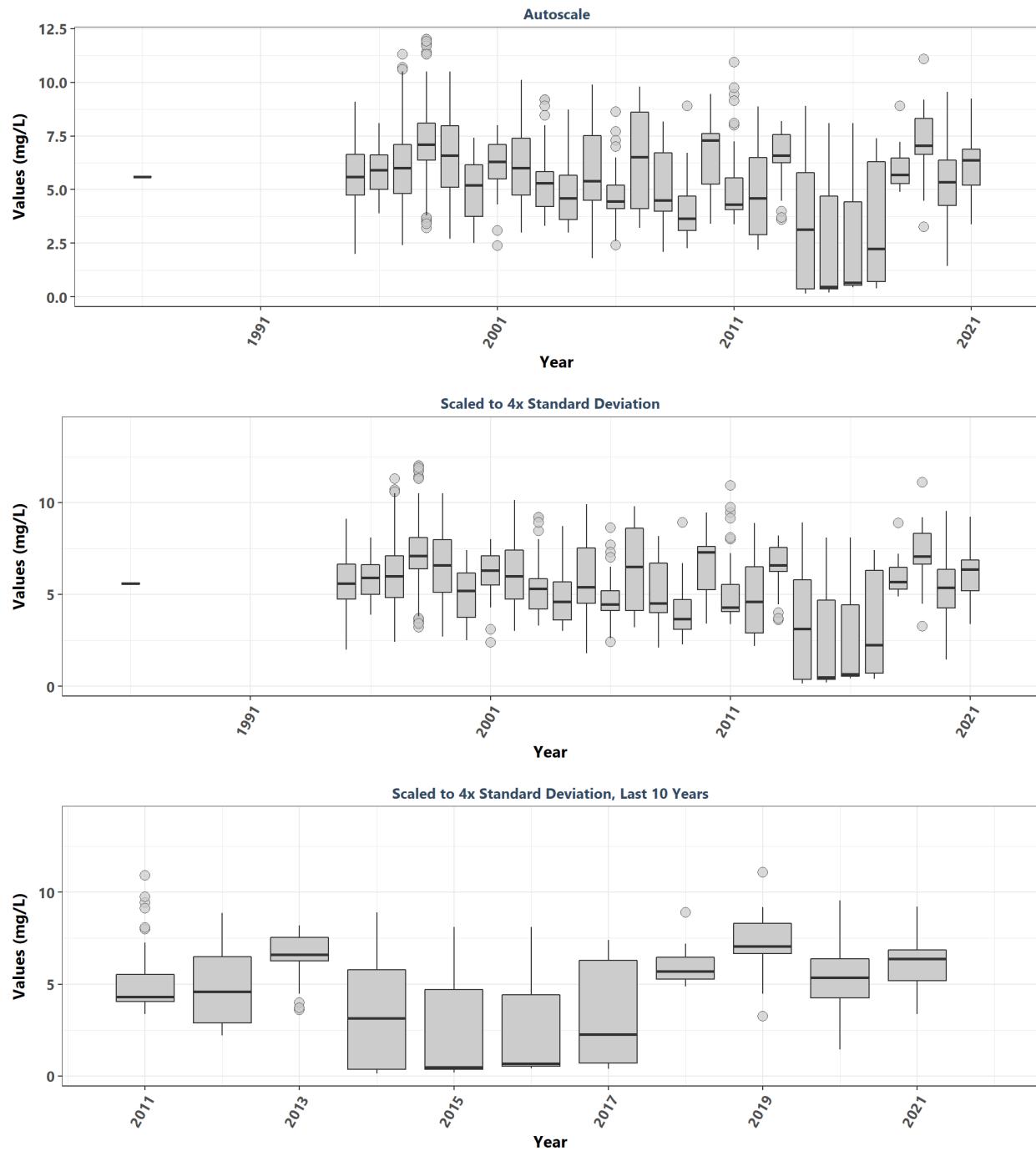
Gasparilla Sound-Charlotte Harbor Aquatic Preserve
By Year & Month



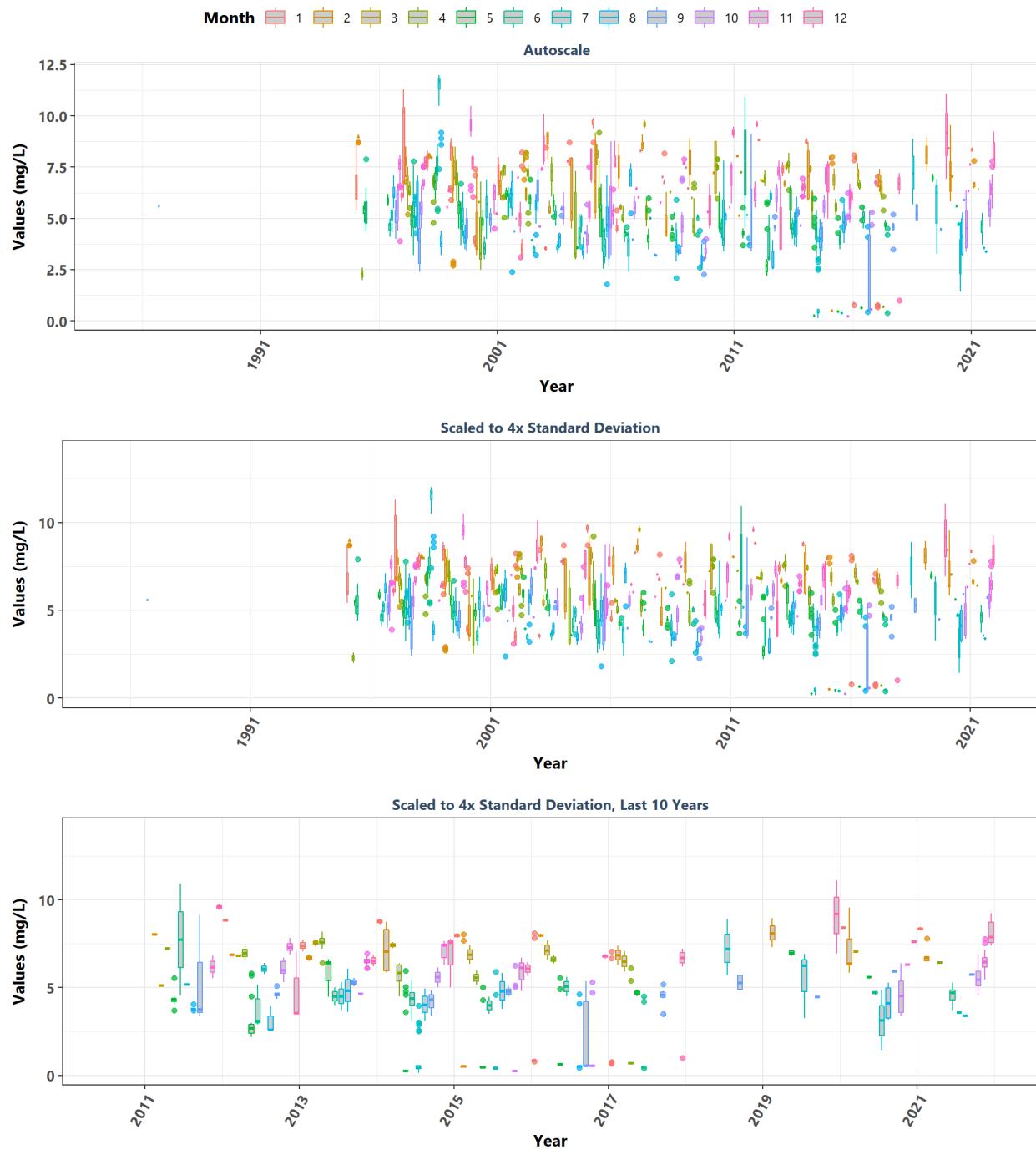
Gasparilla Sound-Charlotte Harbor Aquatic Preserve
By Month



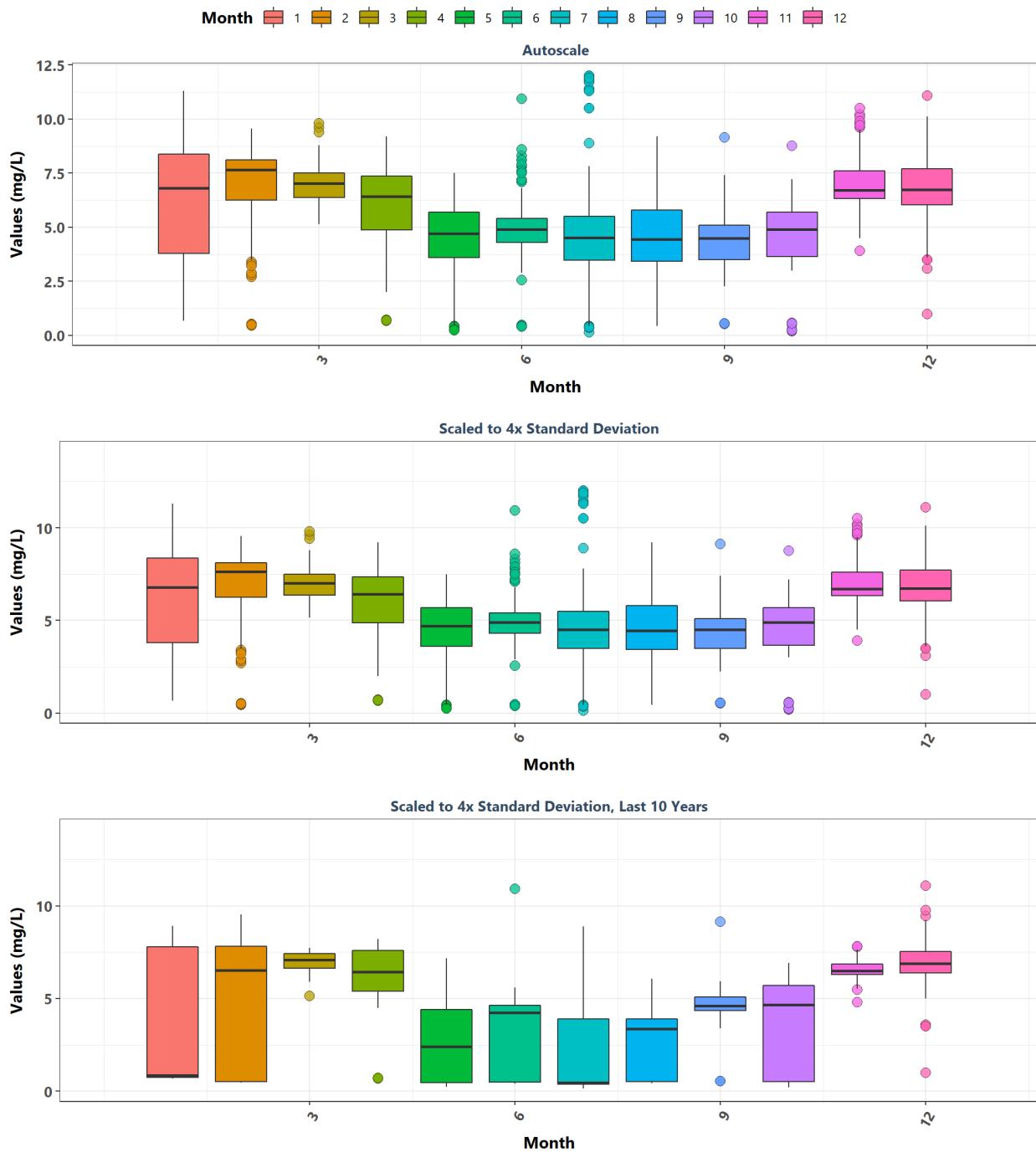
Guana River Marsh Aquatic Preserve
By Year



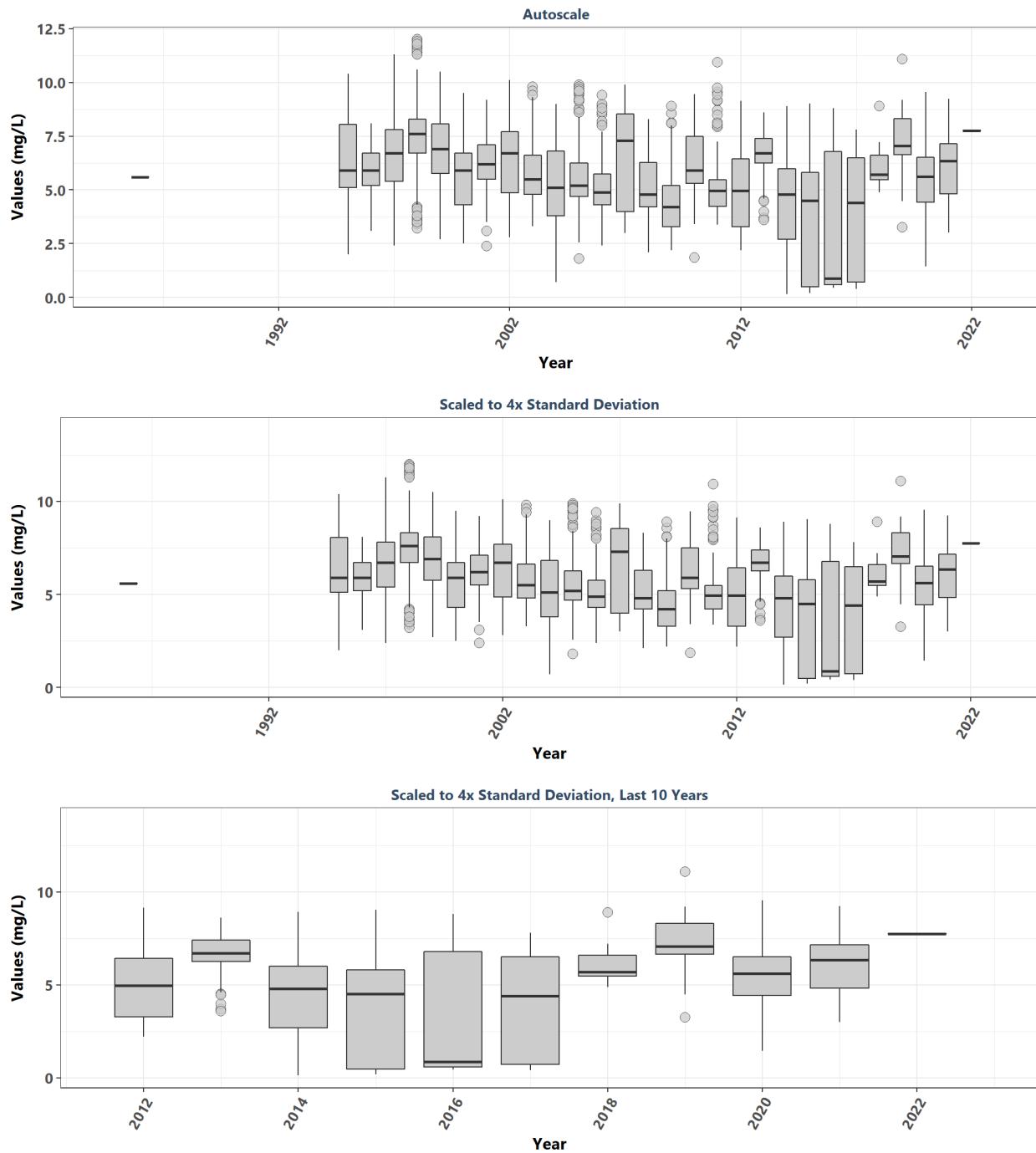
Guana River Marsh Aquatic Preserve
By Year & Month



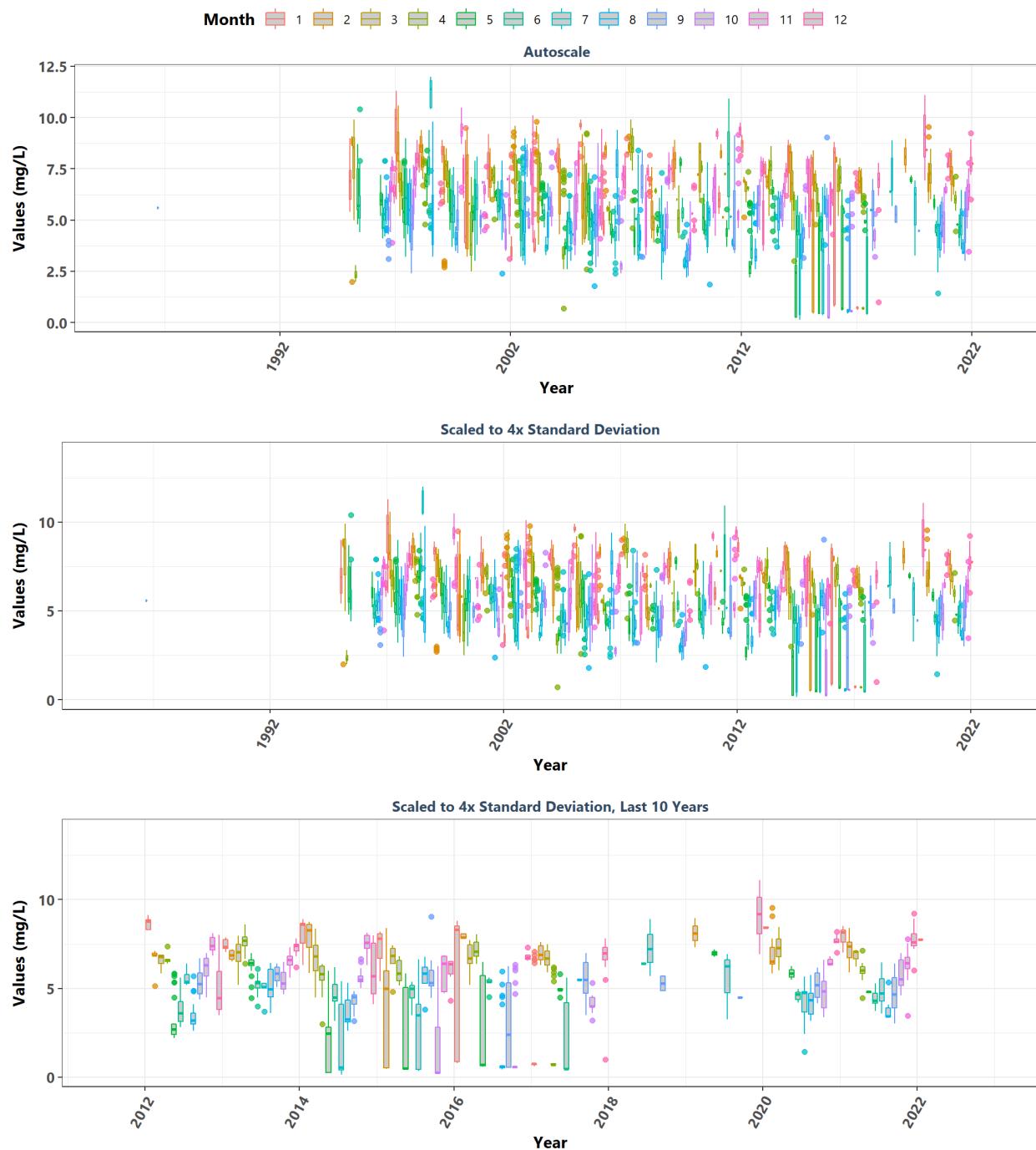
Guana River Marsh Aquatic Preserve
By Month



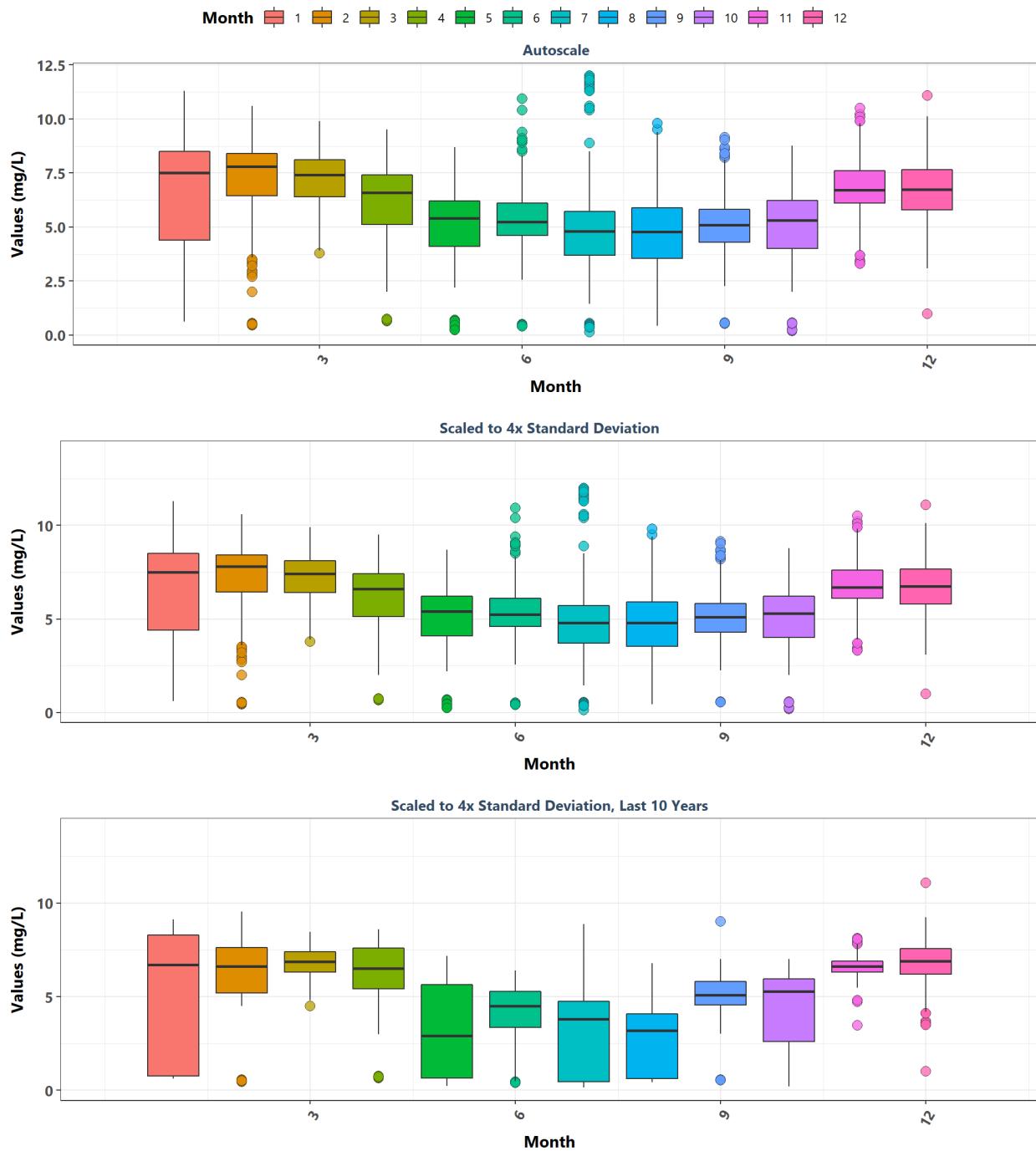
Guana Tolomato Matanzas National Estuarine Research Reserve
By Year



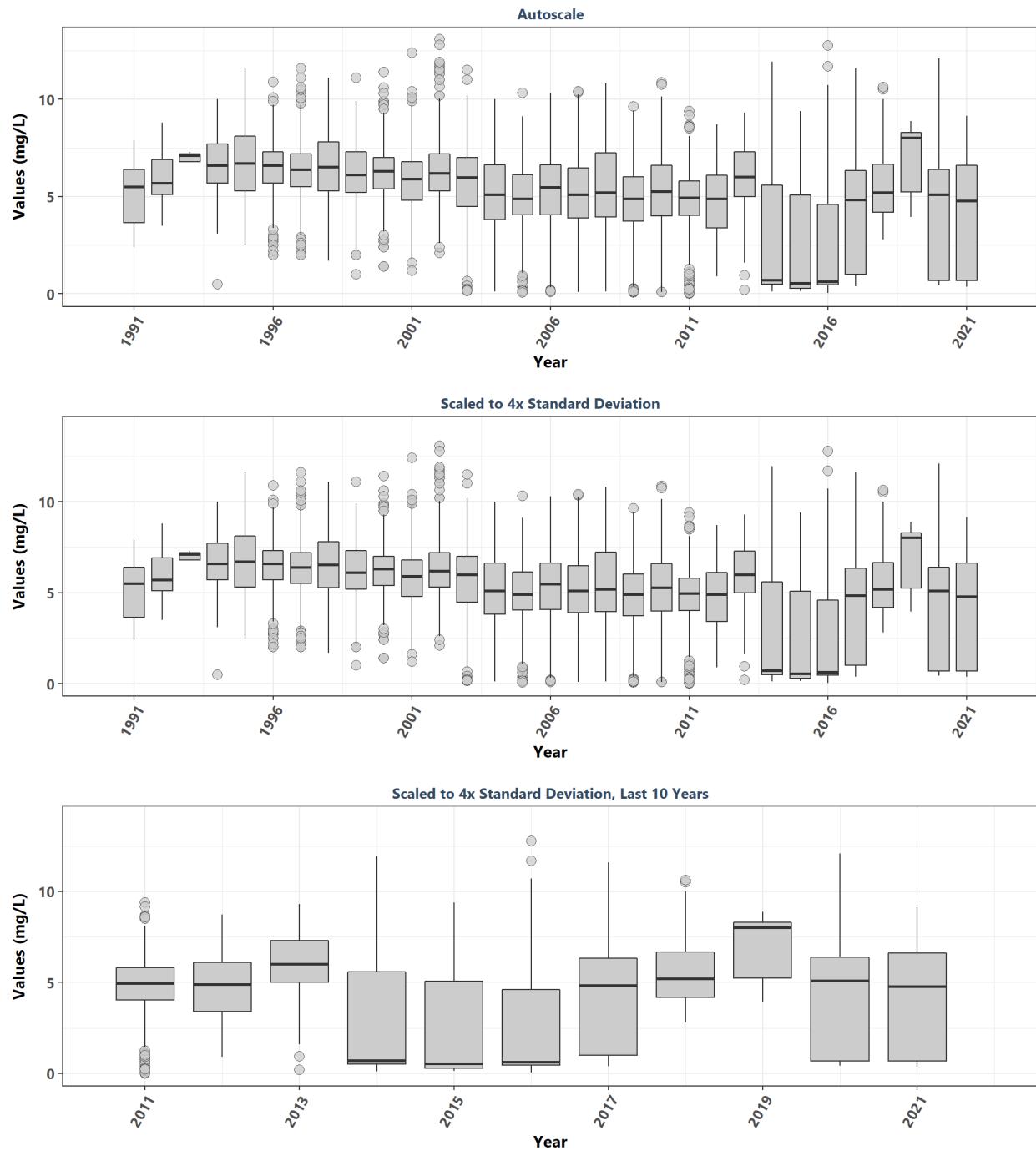
Guana Tolomato Matanzas National Estuarine Research Reserve
By Year & Month



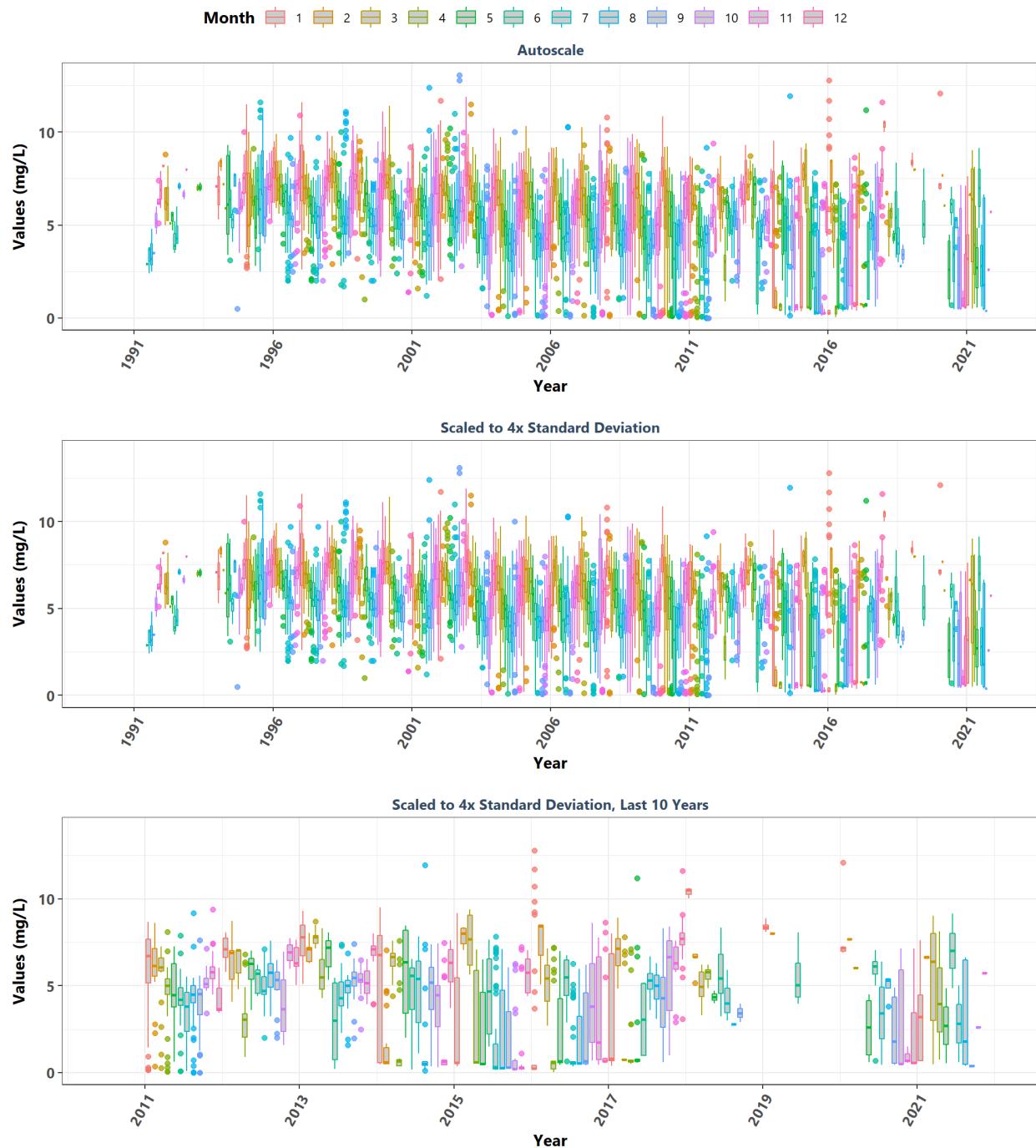
Guana Tolomato Matanzas National Estuarine Research Reserve
By Month



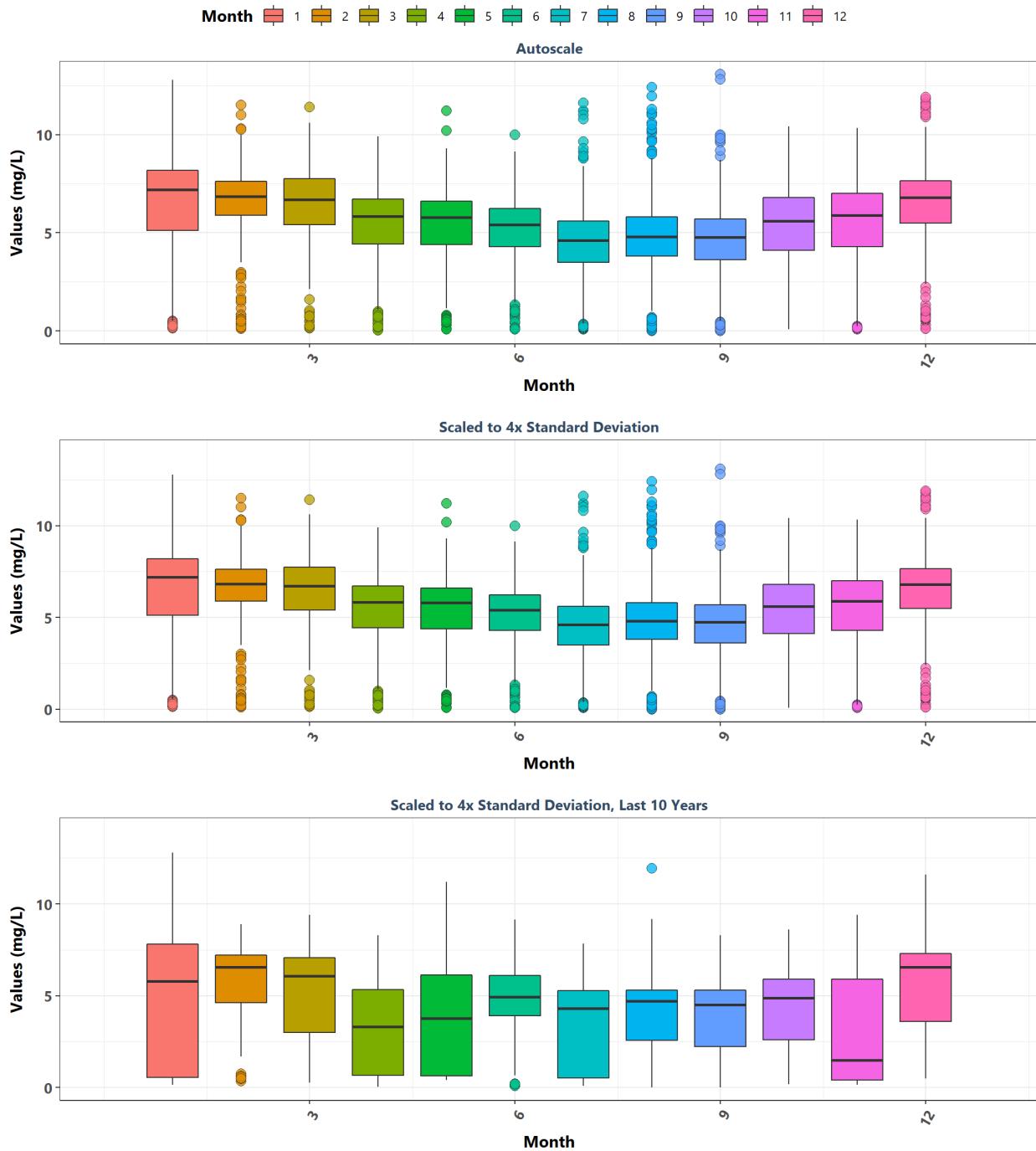
Indian River-Malabar to Vero Beach Aquatic Preserve
By Year



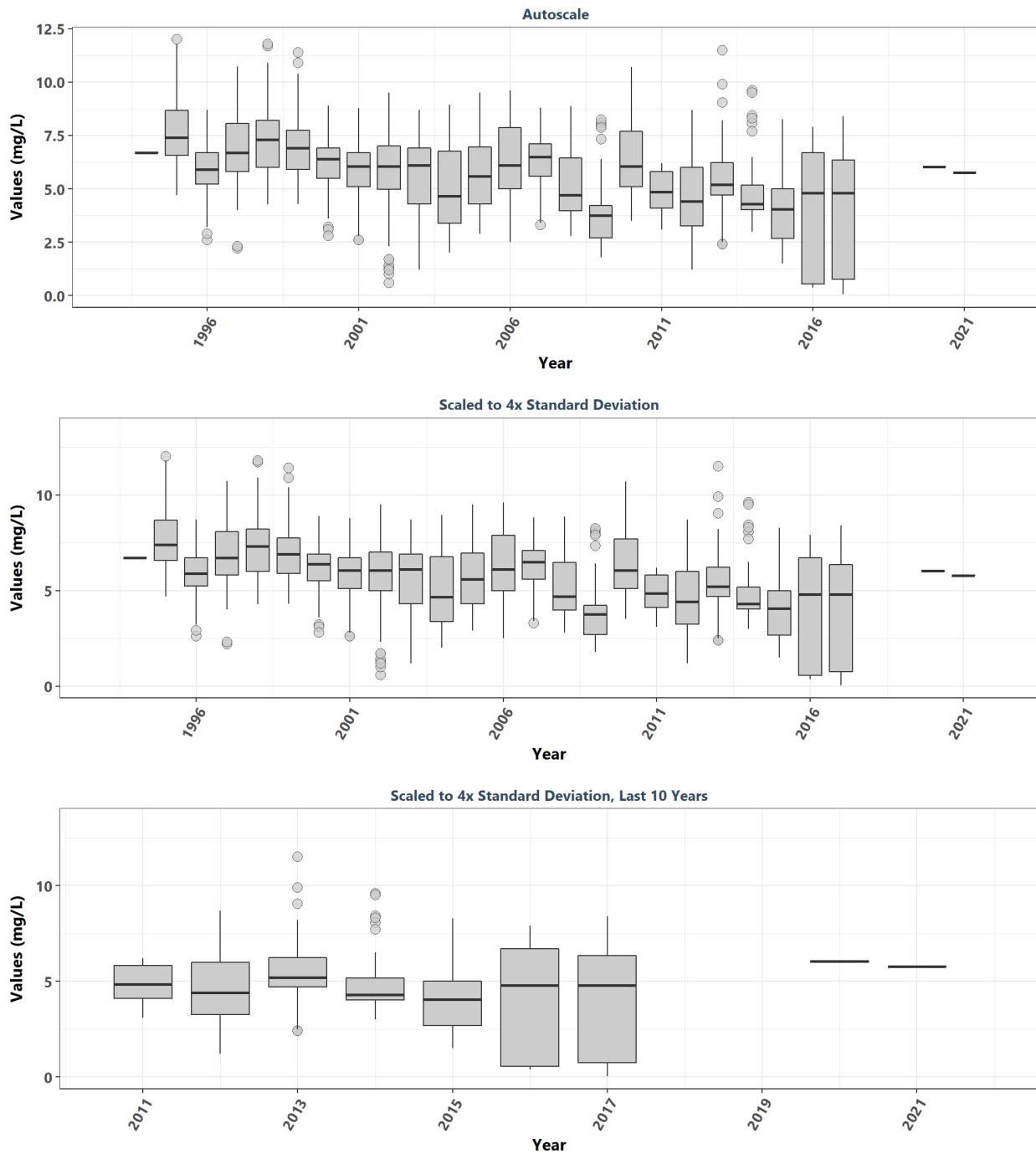
Indian River-Malabar to Vero Beach Aquatic Preserve
By Year & Month



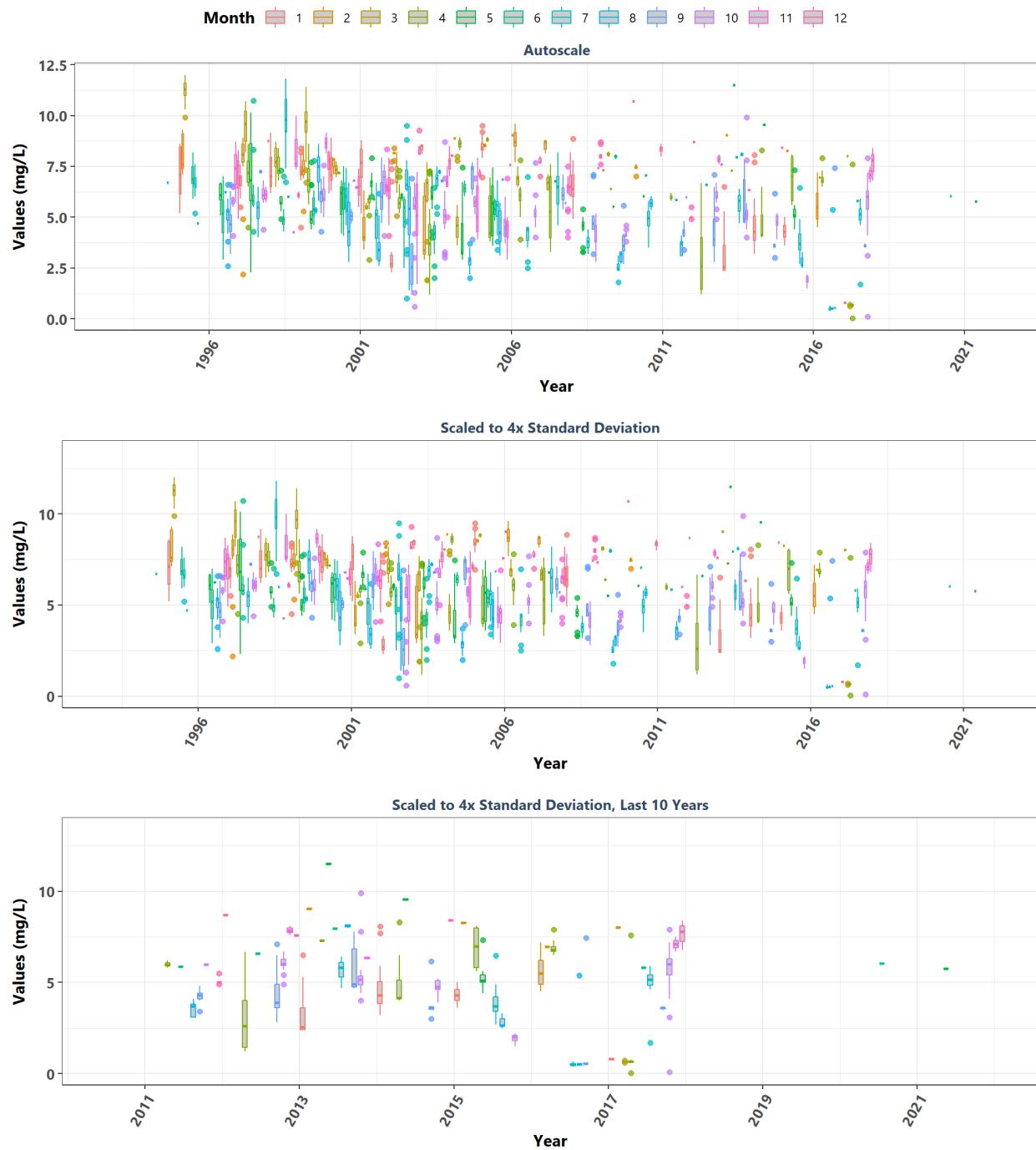
Indian River-Malabar to Vero Beach Aquatic Preserve
By Month



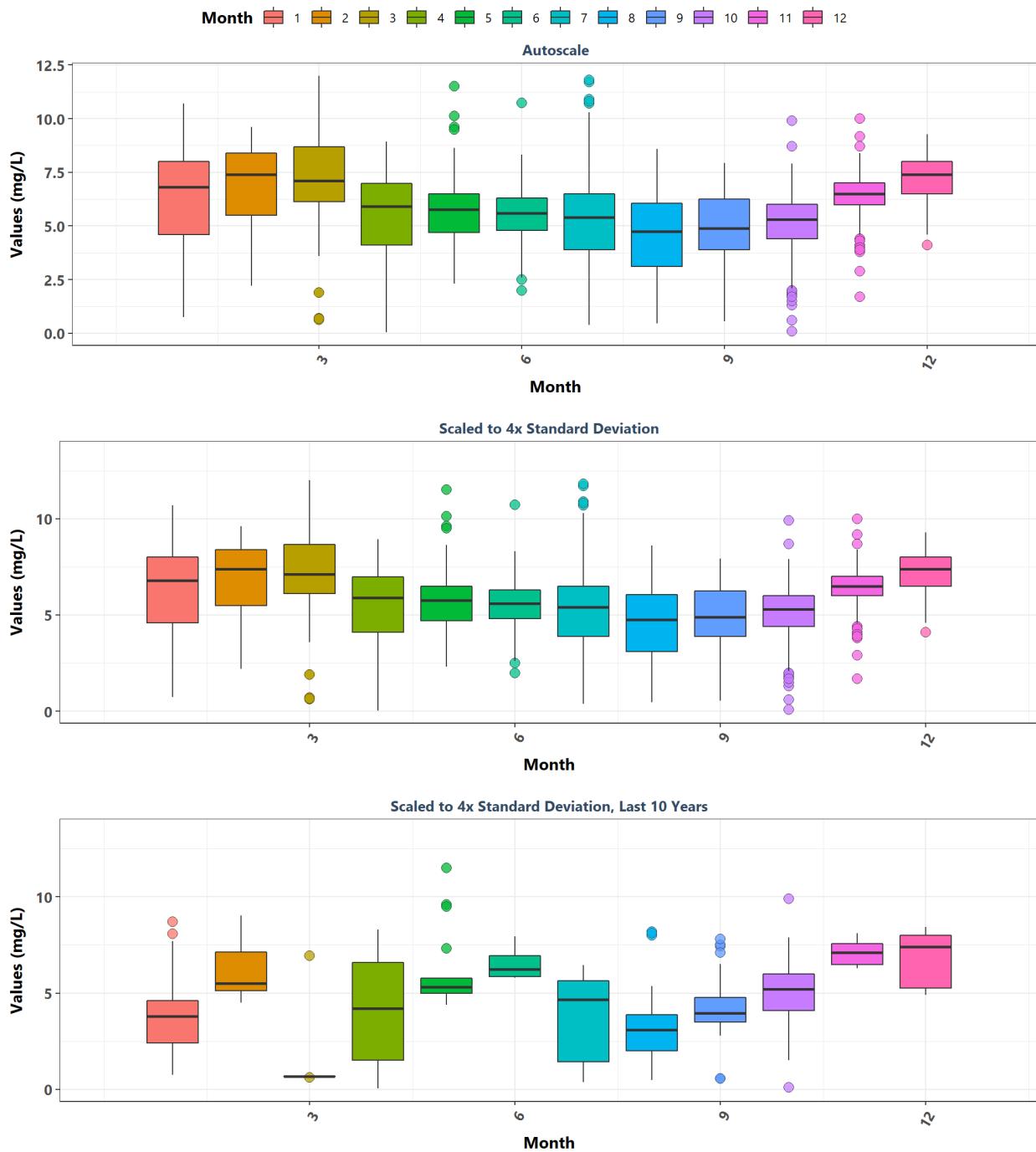
Indian River-Vero Beach to Ft. Pierce Aquatic Preserve
By Year



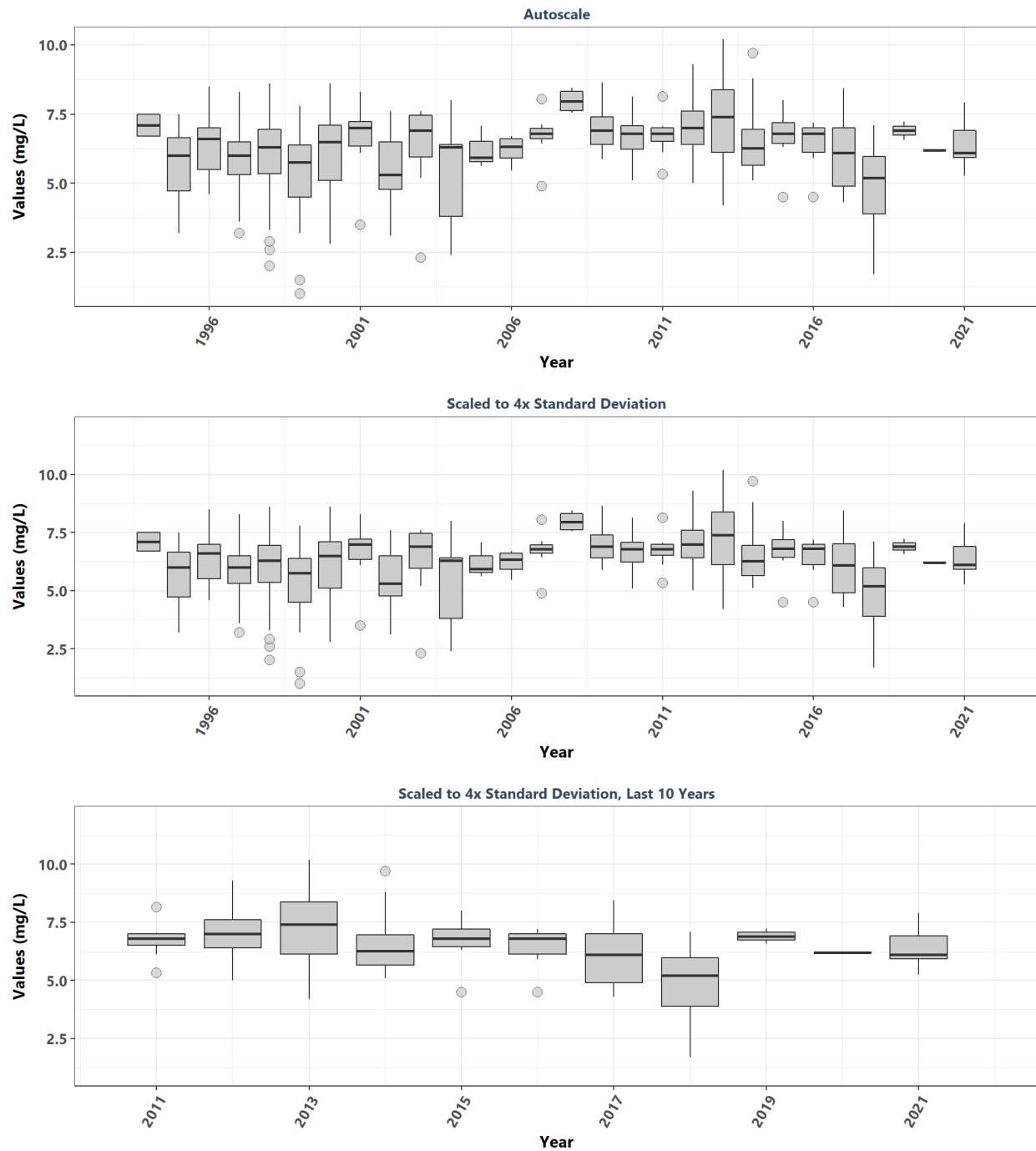
Indian River-Vero Beach to Ft. Pierce Aquatic Preserve
By Year & Month



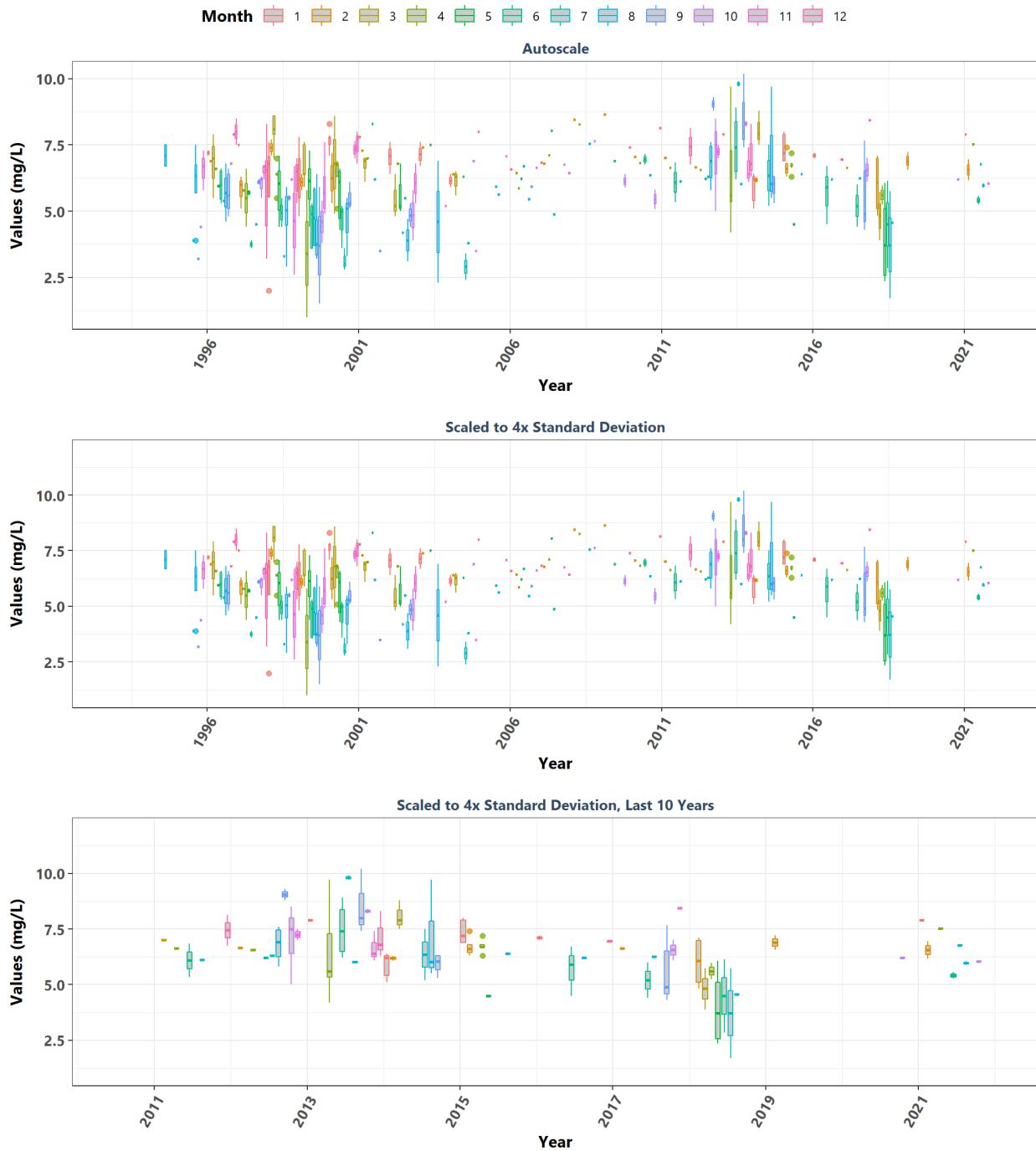
Indian River-Vero Beach to Ft. Pierce Aquatic Preserve
By Month



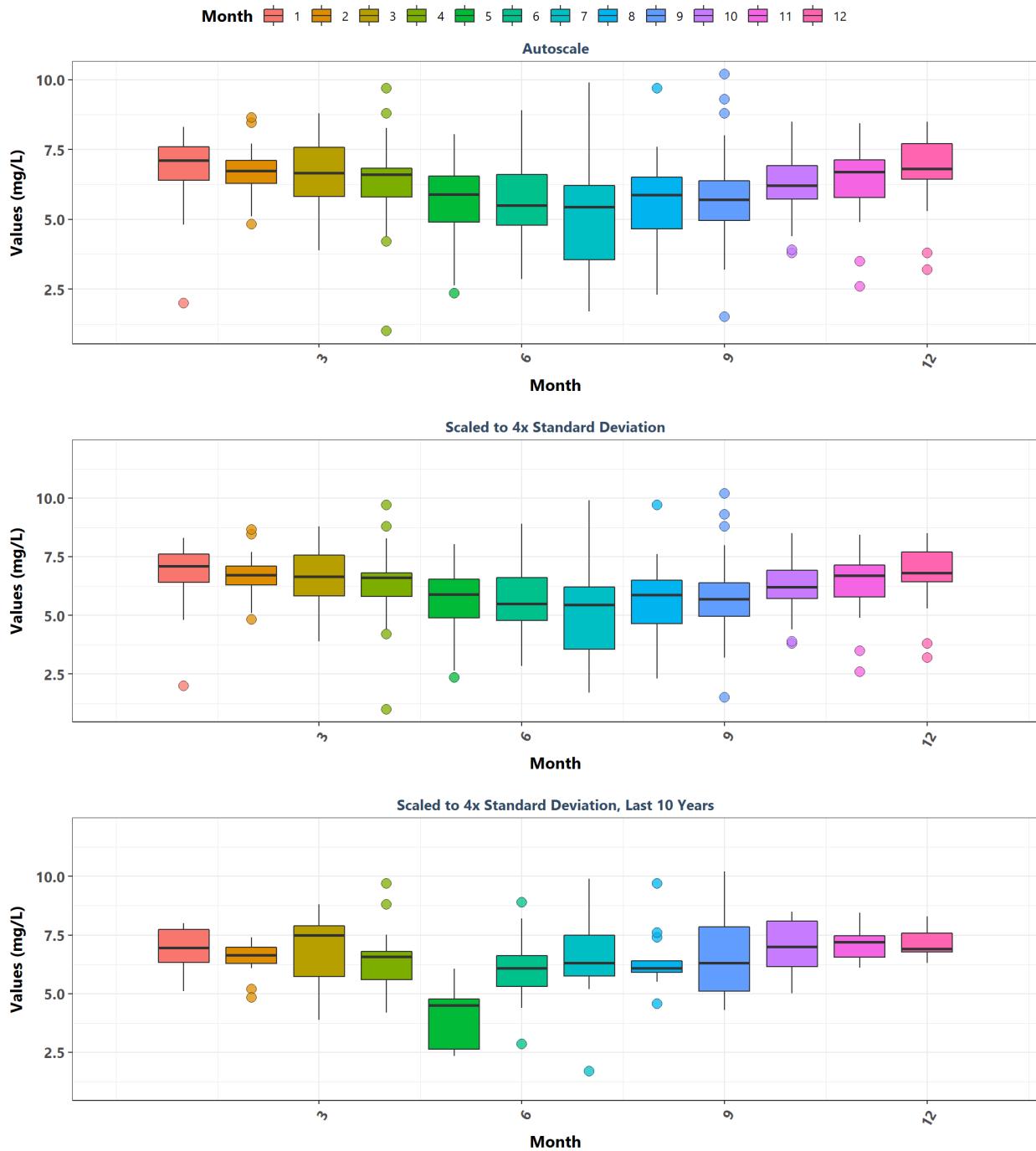
Jensen Beach to Jupiter Inlet Aquatic Preserve
By Year



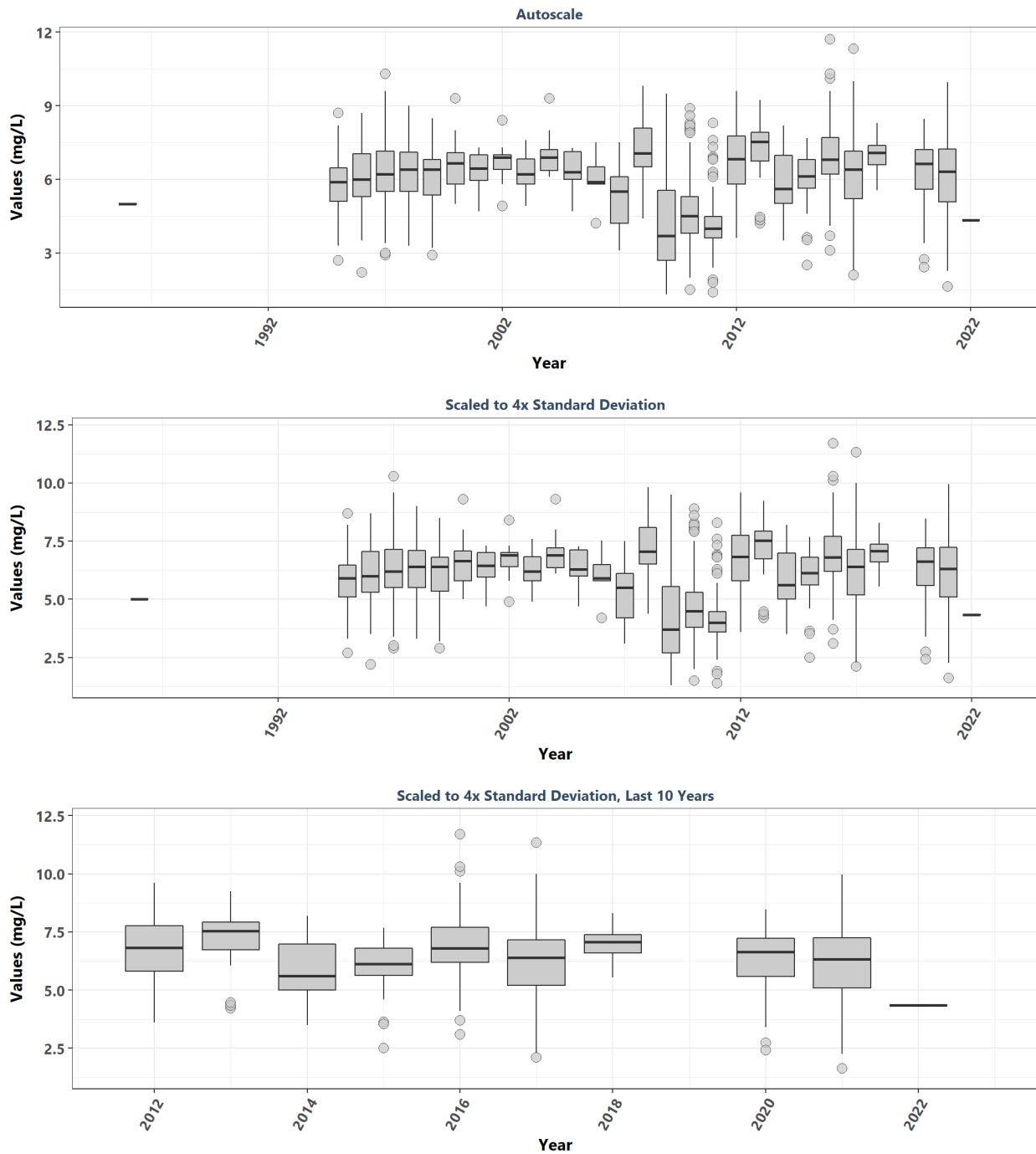
Jensen Beach to Jupiter Inlet Aquatic Preserve
By Year & Month



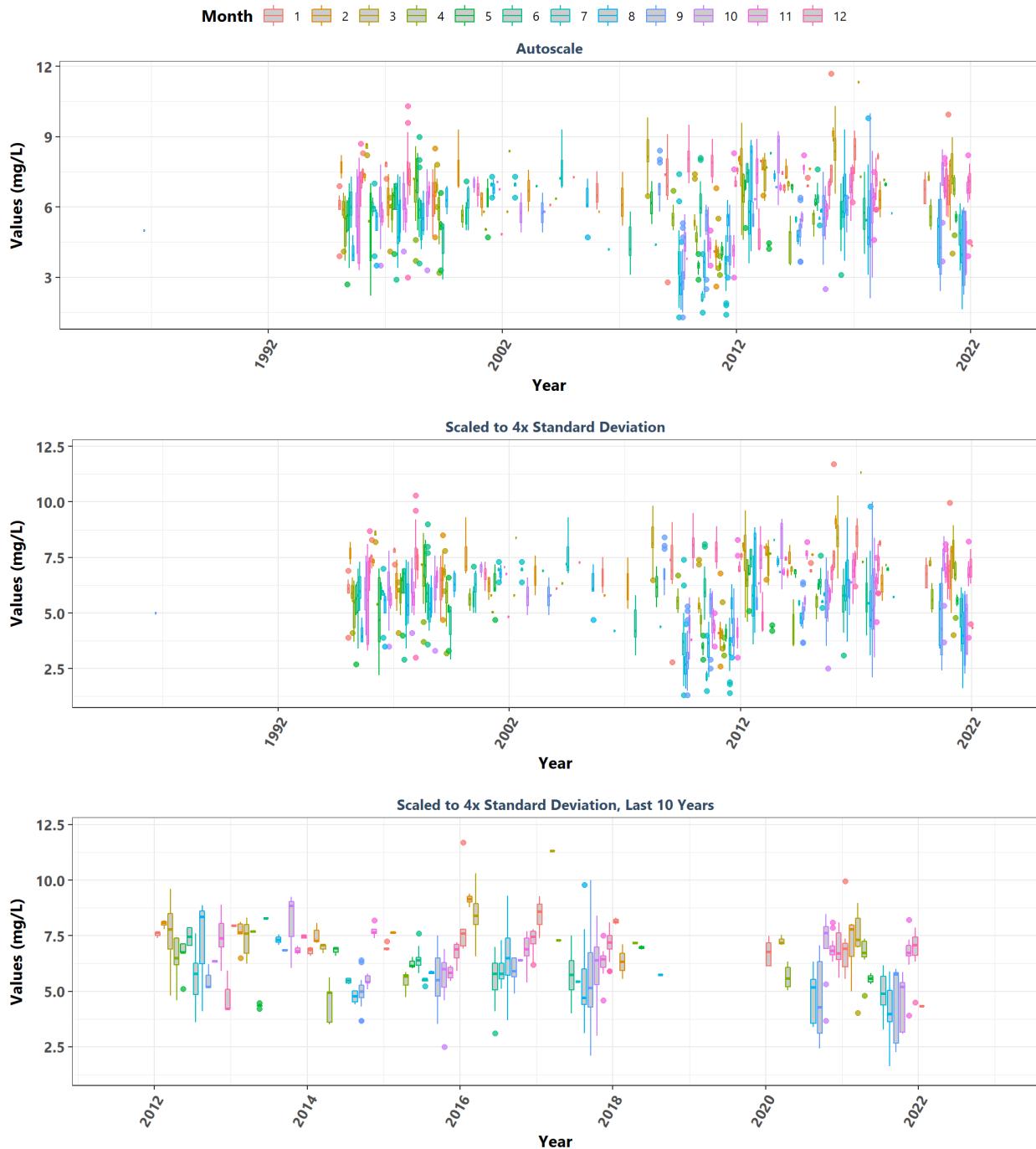
Jensen Beach to Jupiter Inlet Aquatic Preserve
By Month



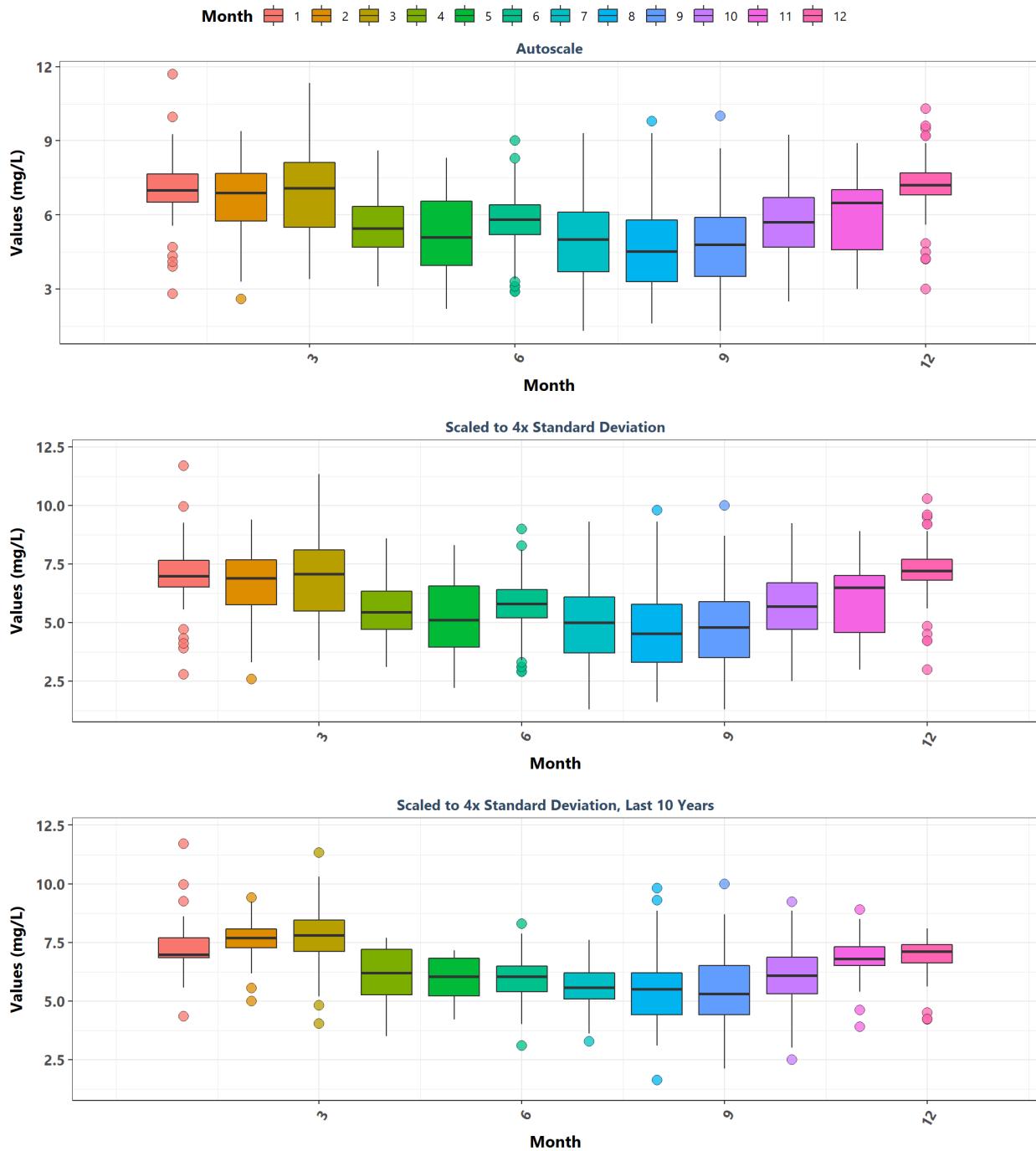
Lemon Bay Aquatic Preserve
By Year



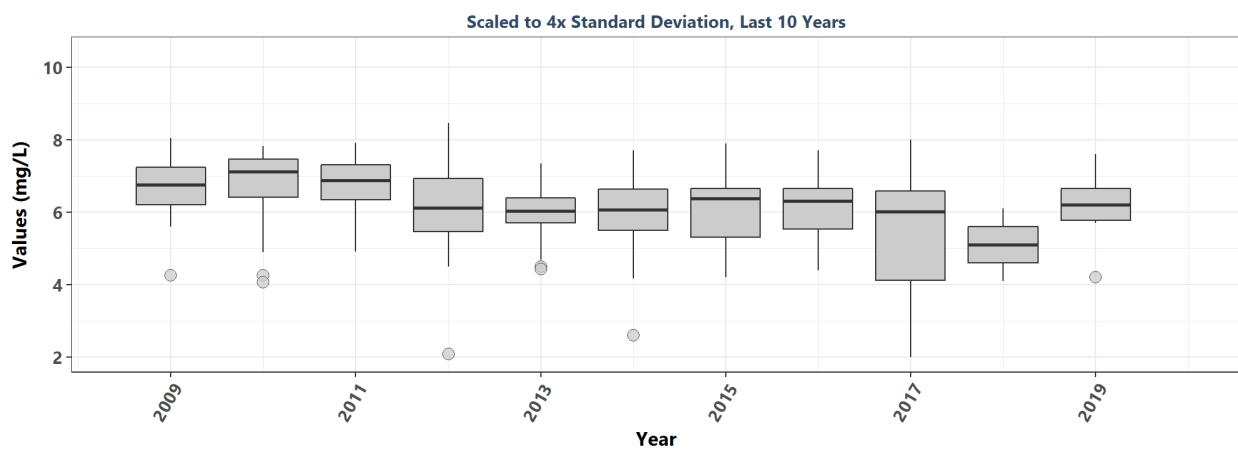
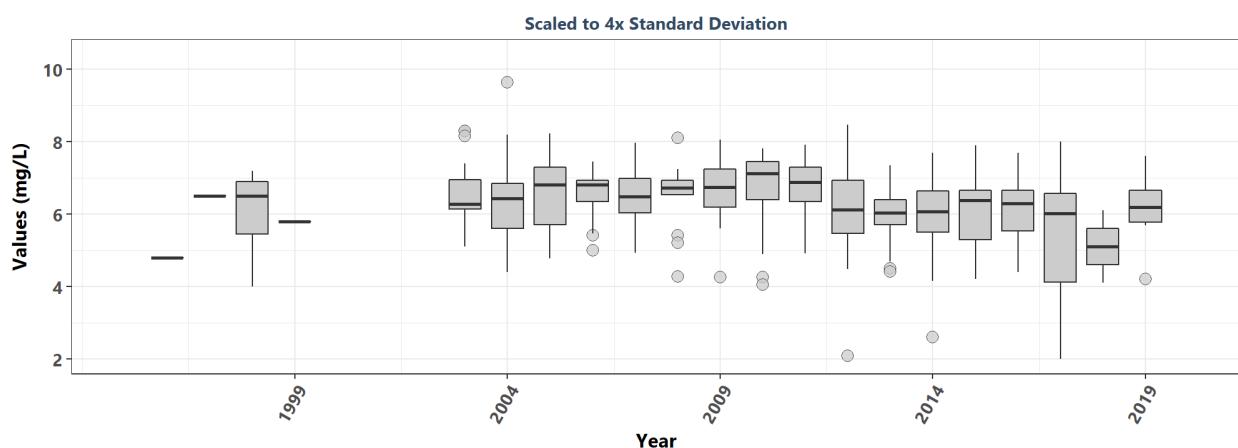
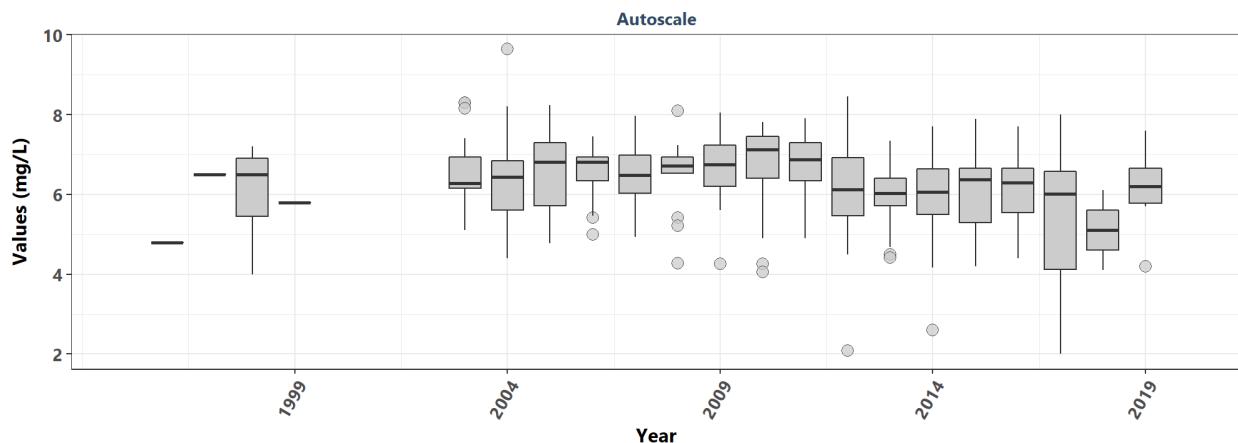
Lemon Bay Aquatic Preserve
By Year & Month



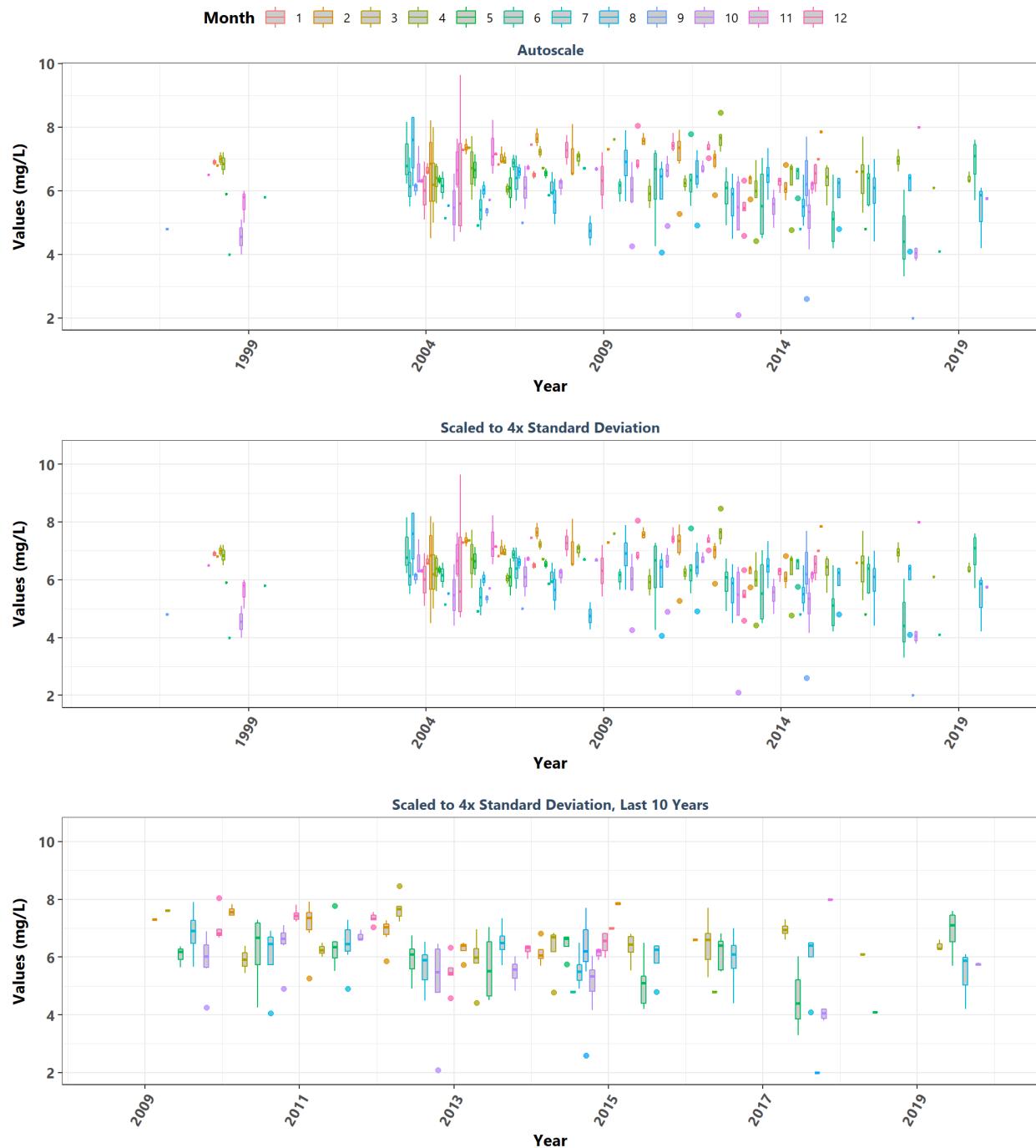
Lemon Bay Aquatic Preserve
By Month



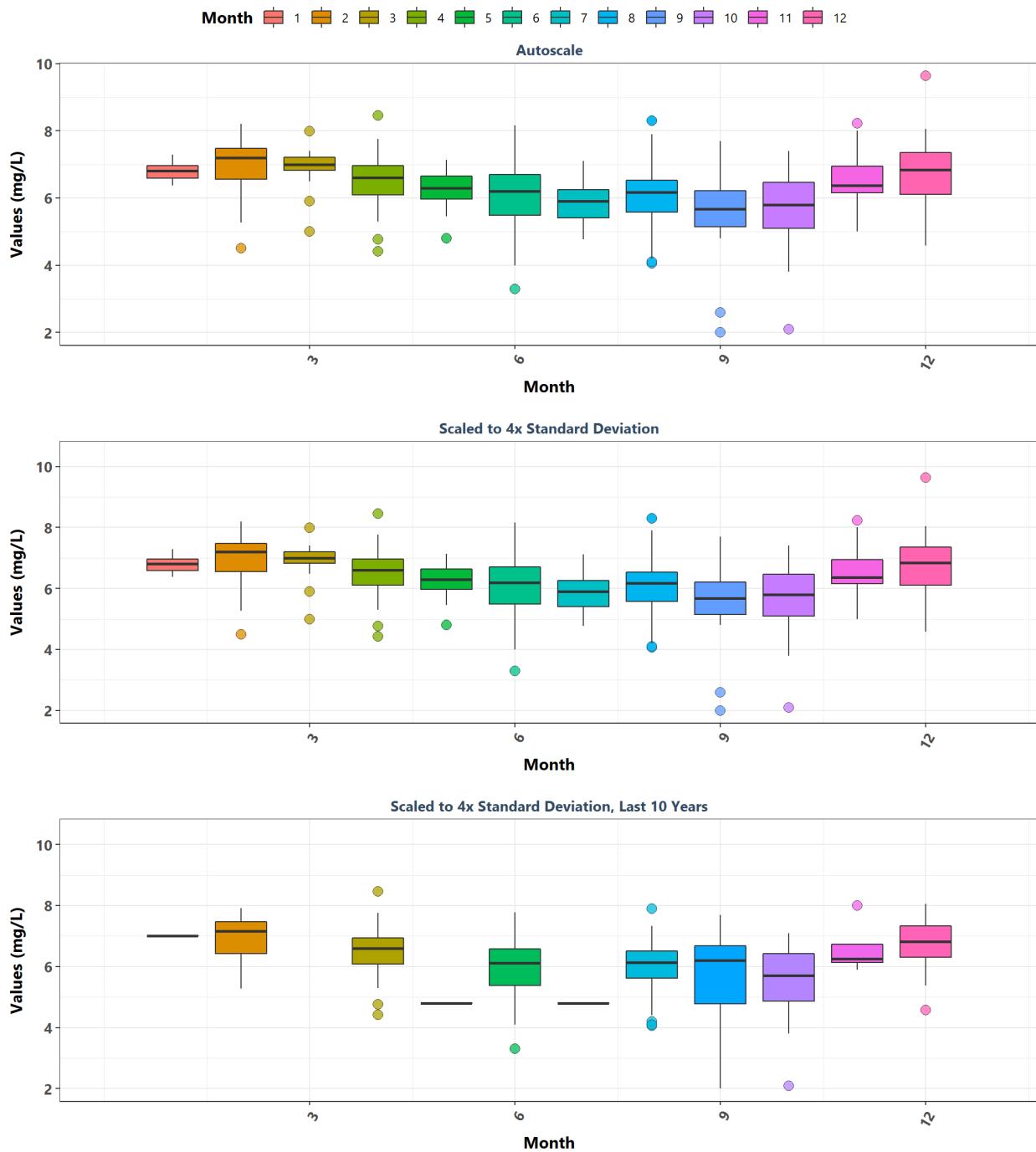
Loxahatchee River-Lake Worth Creek Aquatic Preserve
By Year



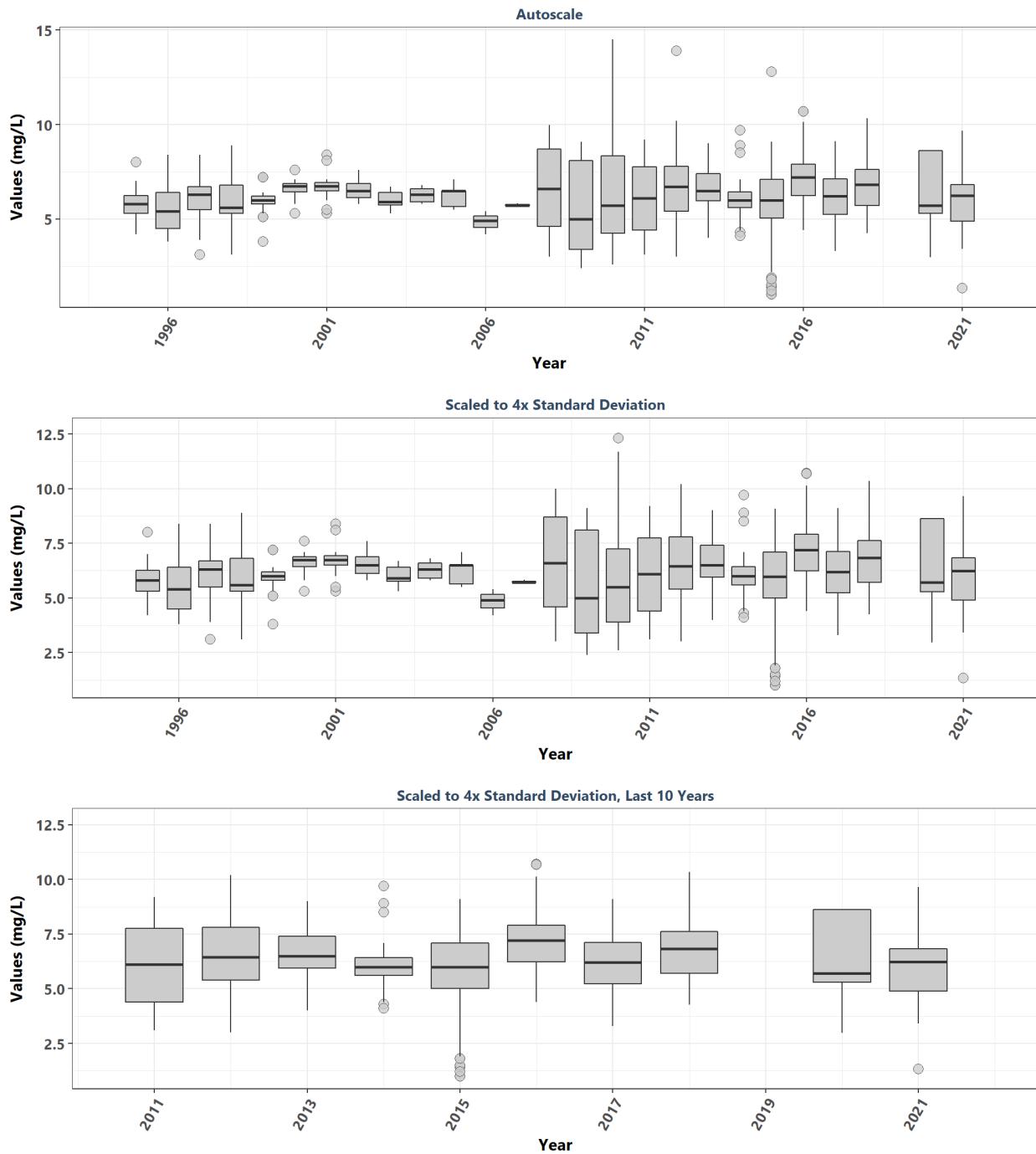
Loxahatchee River-Lake Worth Creek Aquatic Preserve
By Year & Month



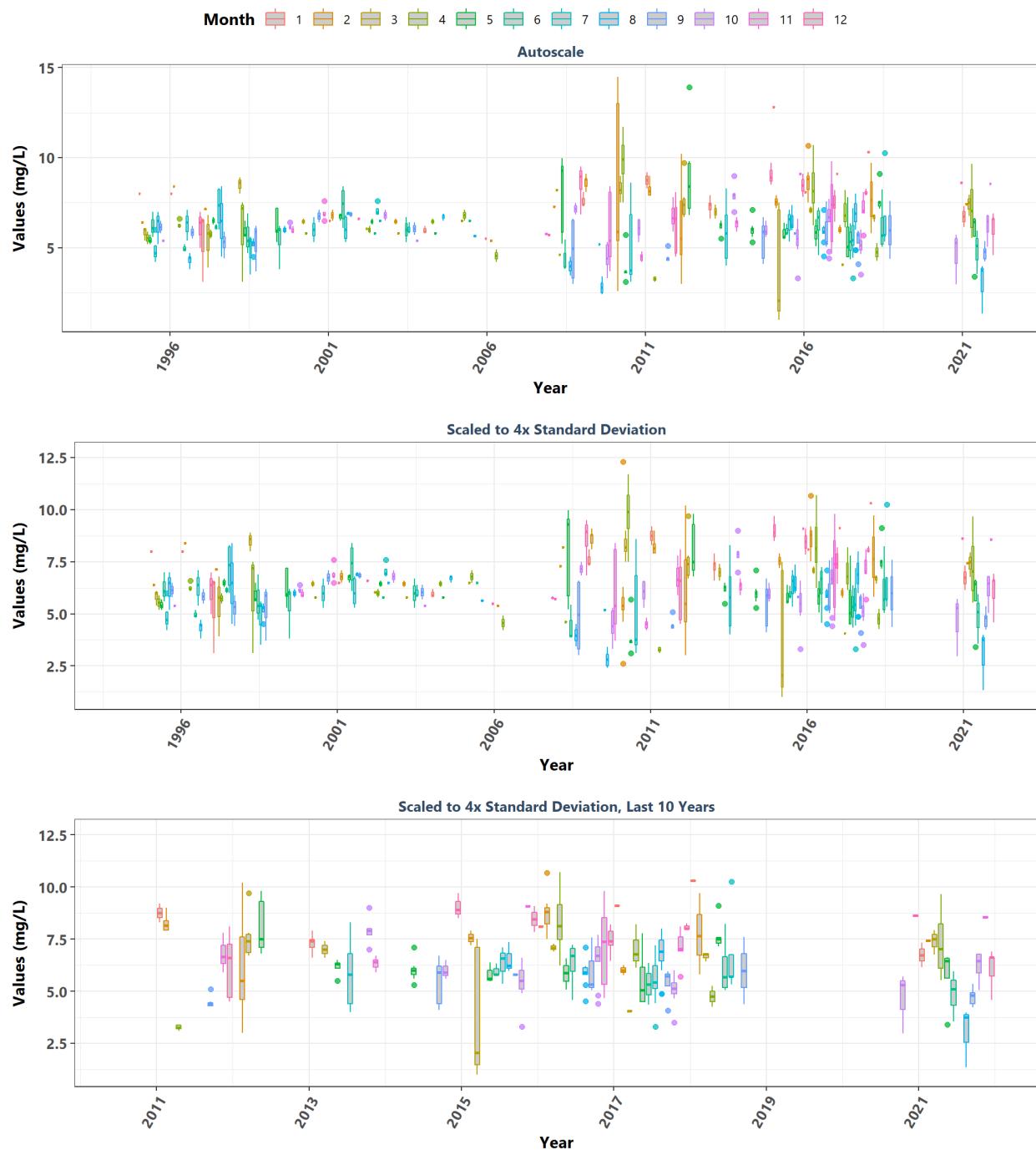
Loxahatchee River-Lake Worth Creek Aquatic Preserve
By Month



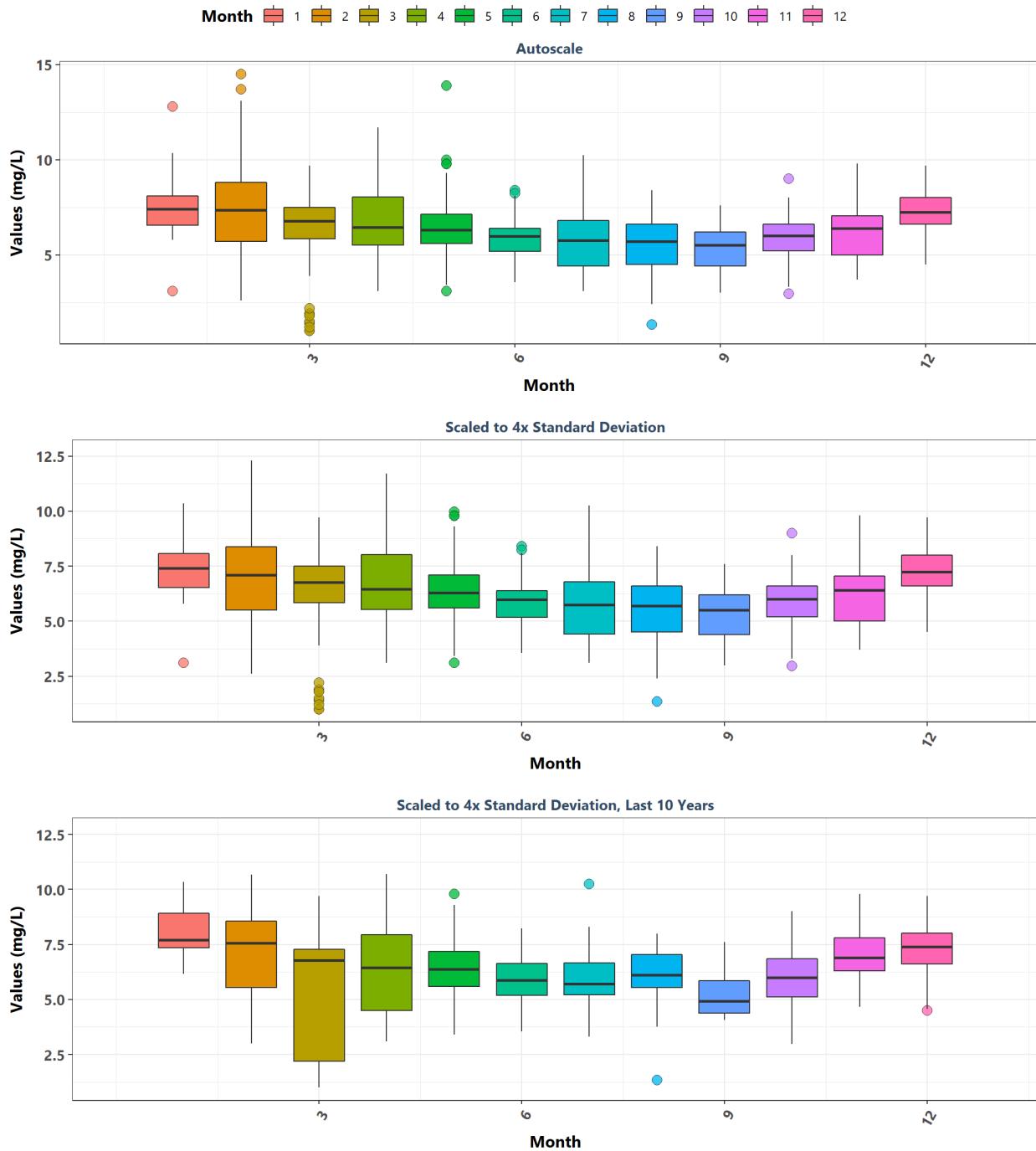
Matlacha Pass Aquatic Preserve
By Year



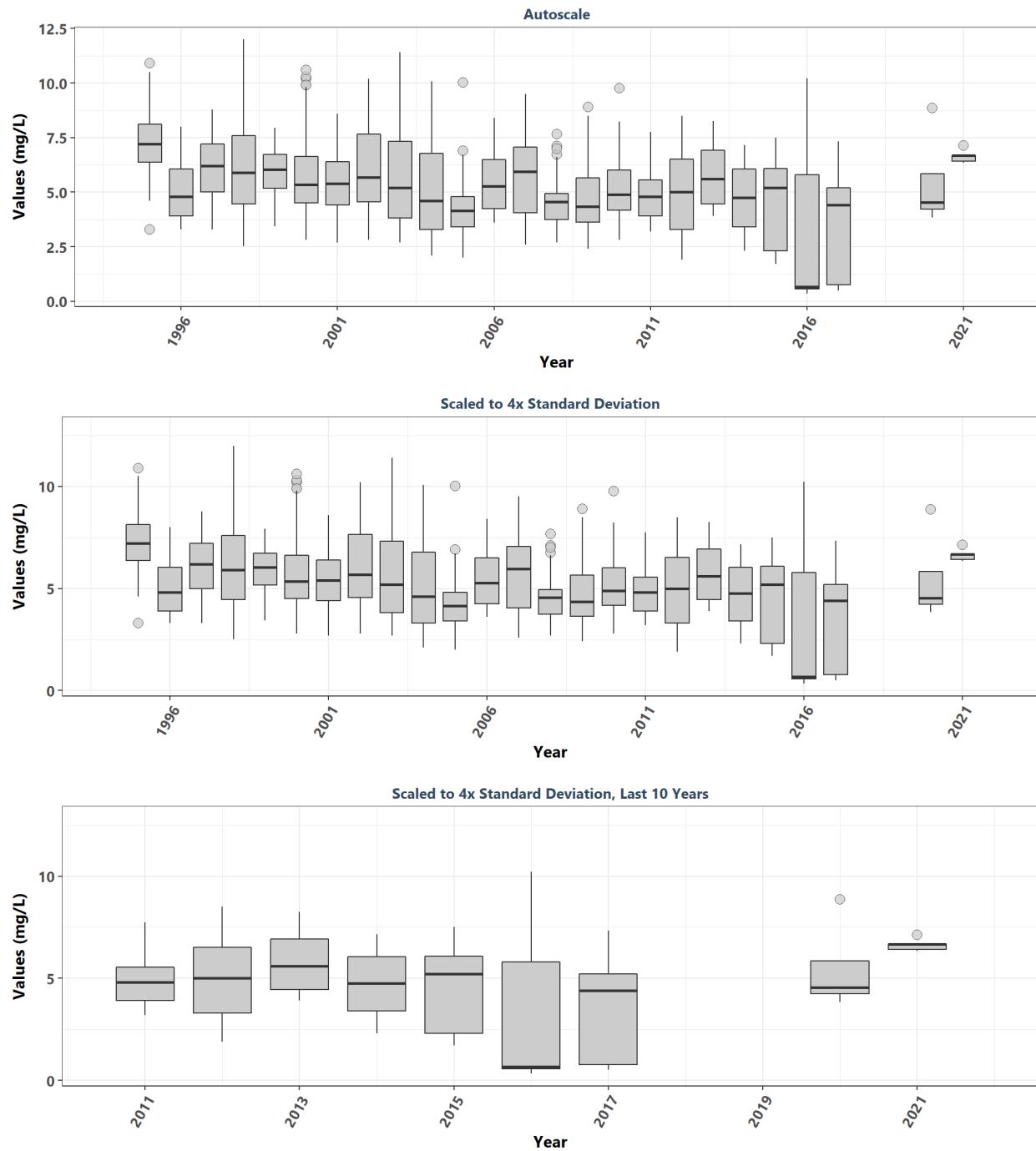
Matlacha Pass Aquatic Preserve
By Year & Month



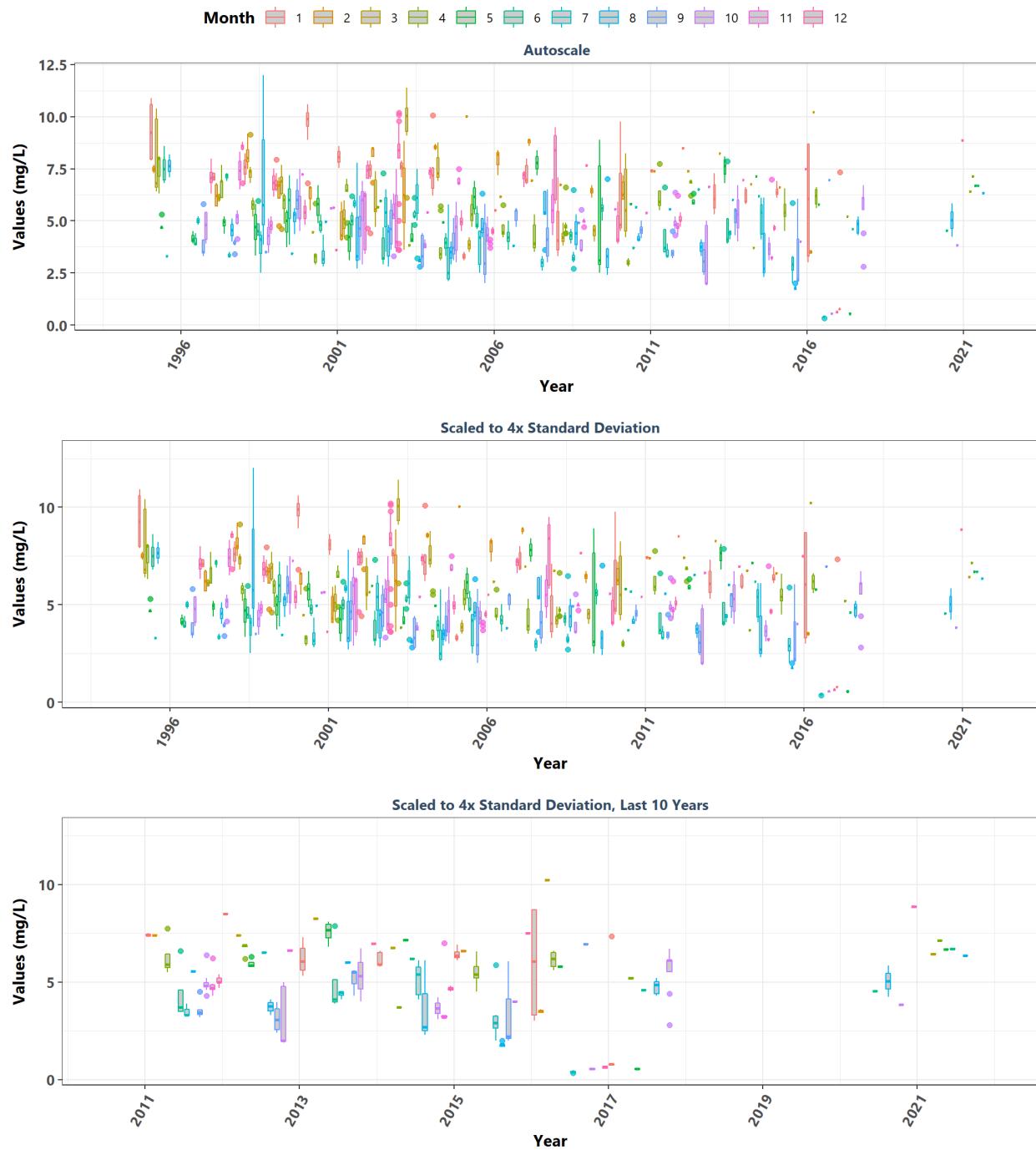
Matlacha Pass Aquatic Preserve
By Month



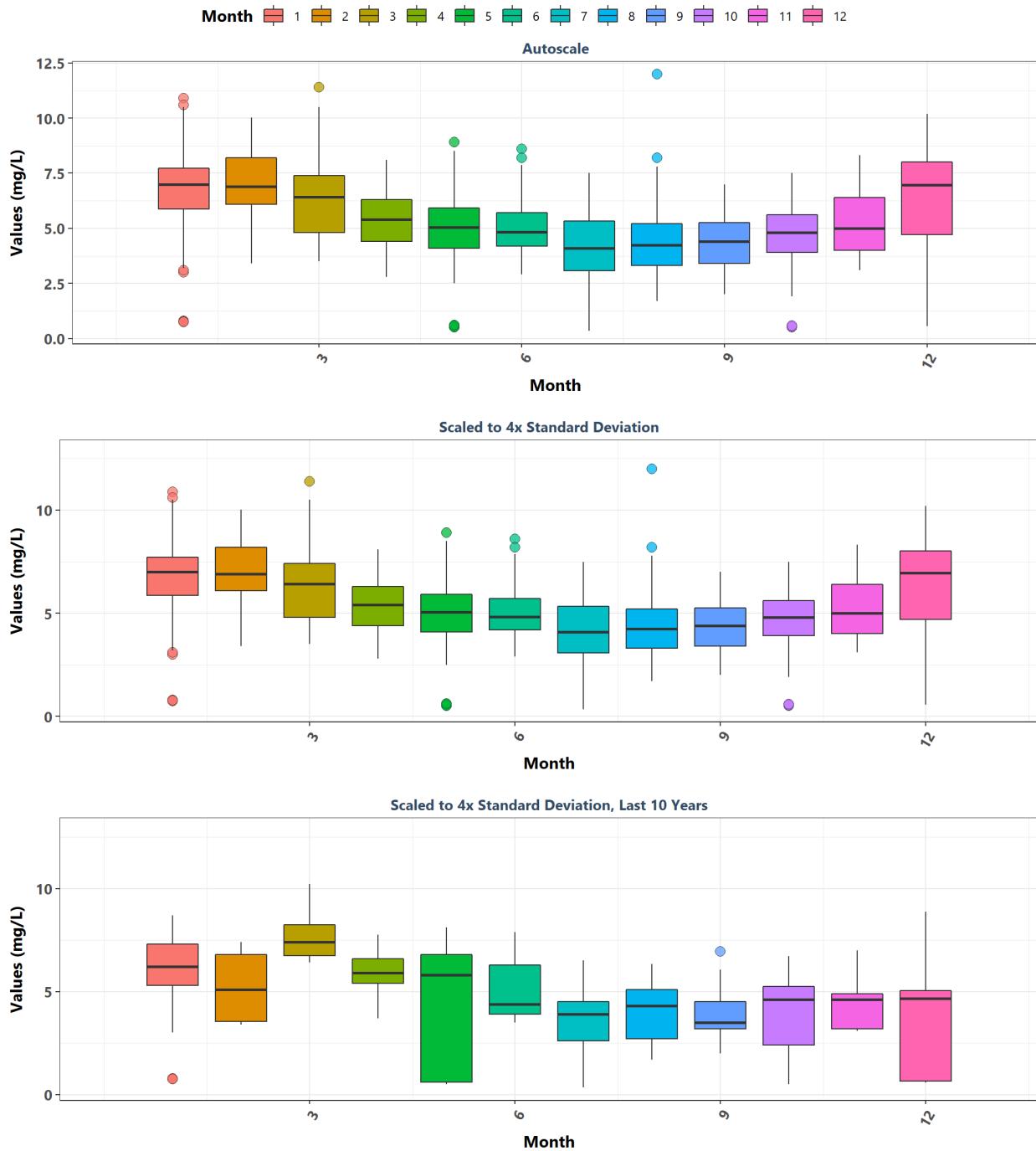
Mosquito Lagoon Aquatic Preserve
By Year



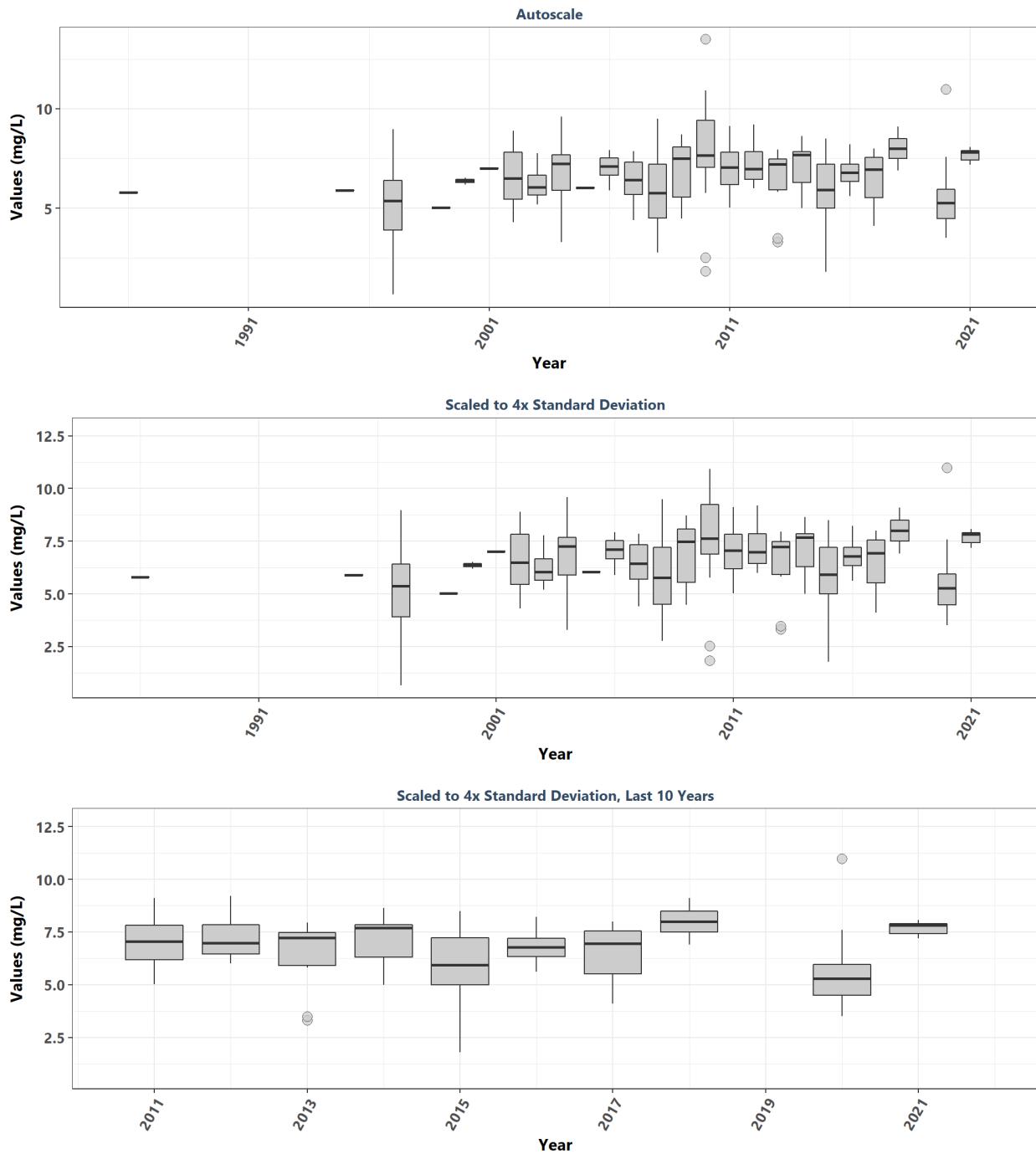
Mosquito Lagoon Aquatic Preserve
By Year & Month



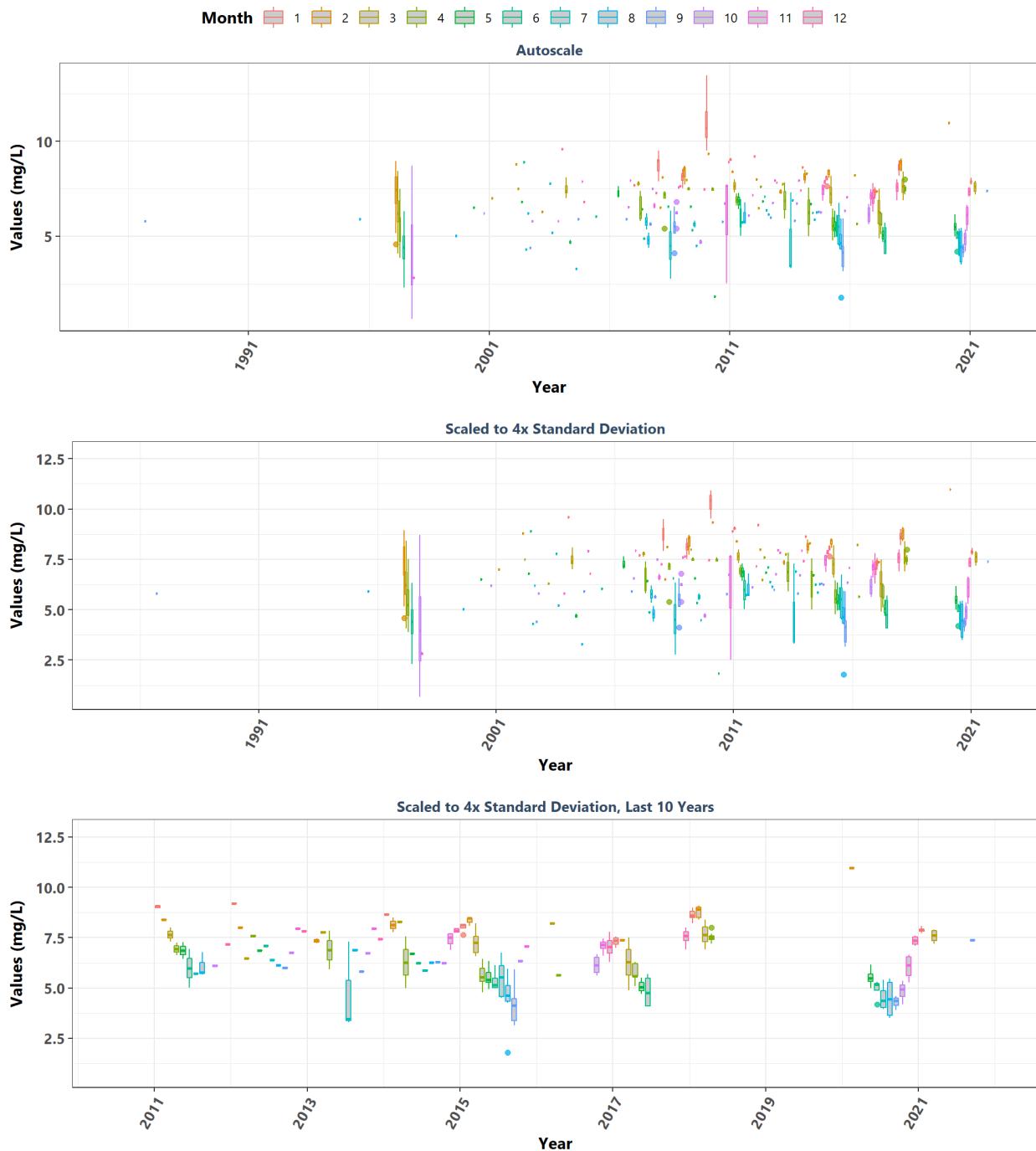
Mosquito Lagoon Aquatic Preserve
By Month



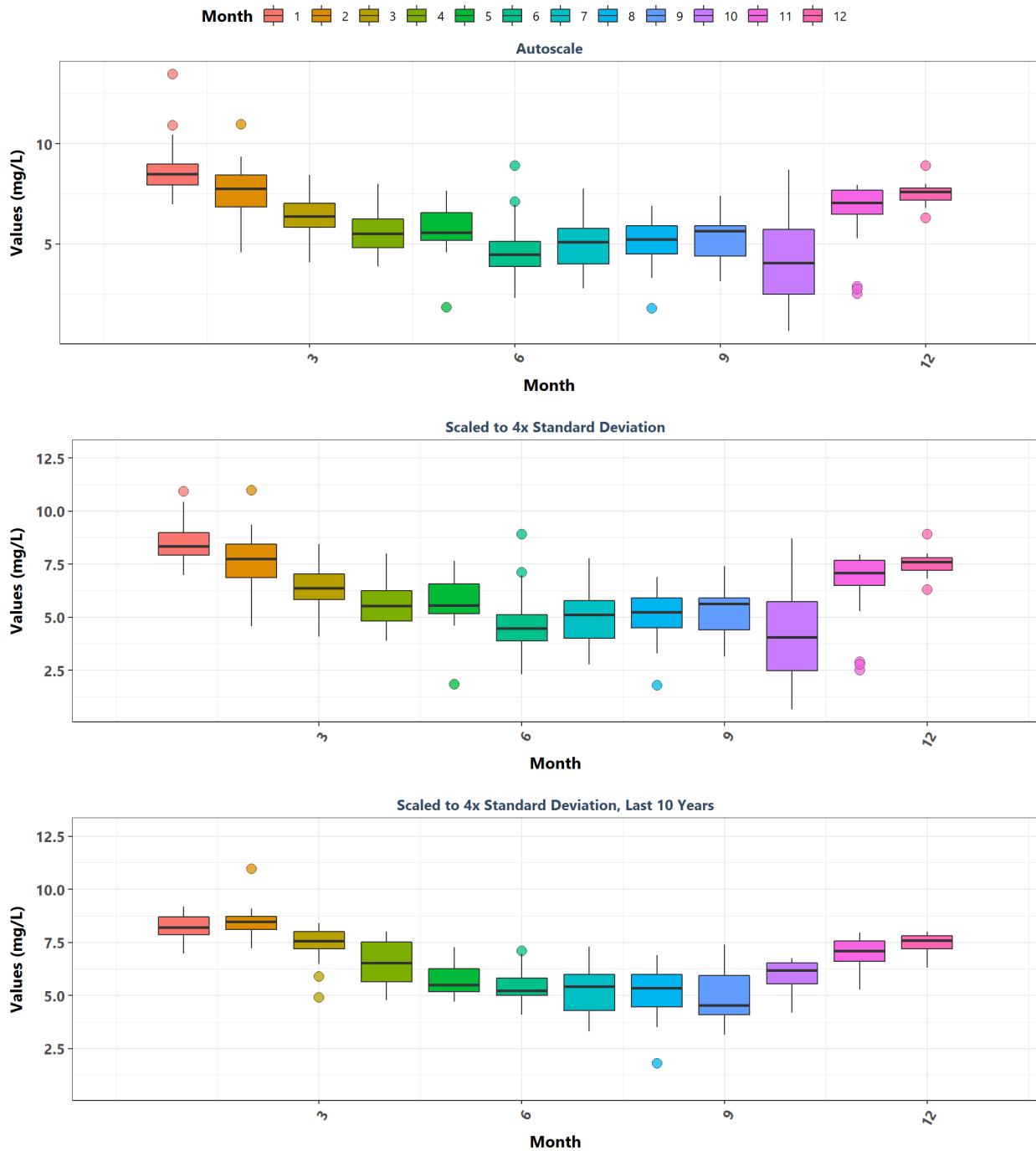
Nassau River-St. Johns River Marshes Aquatic Preserve
By Year



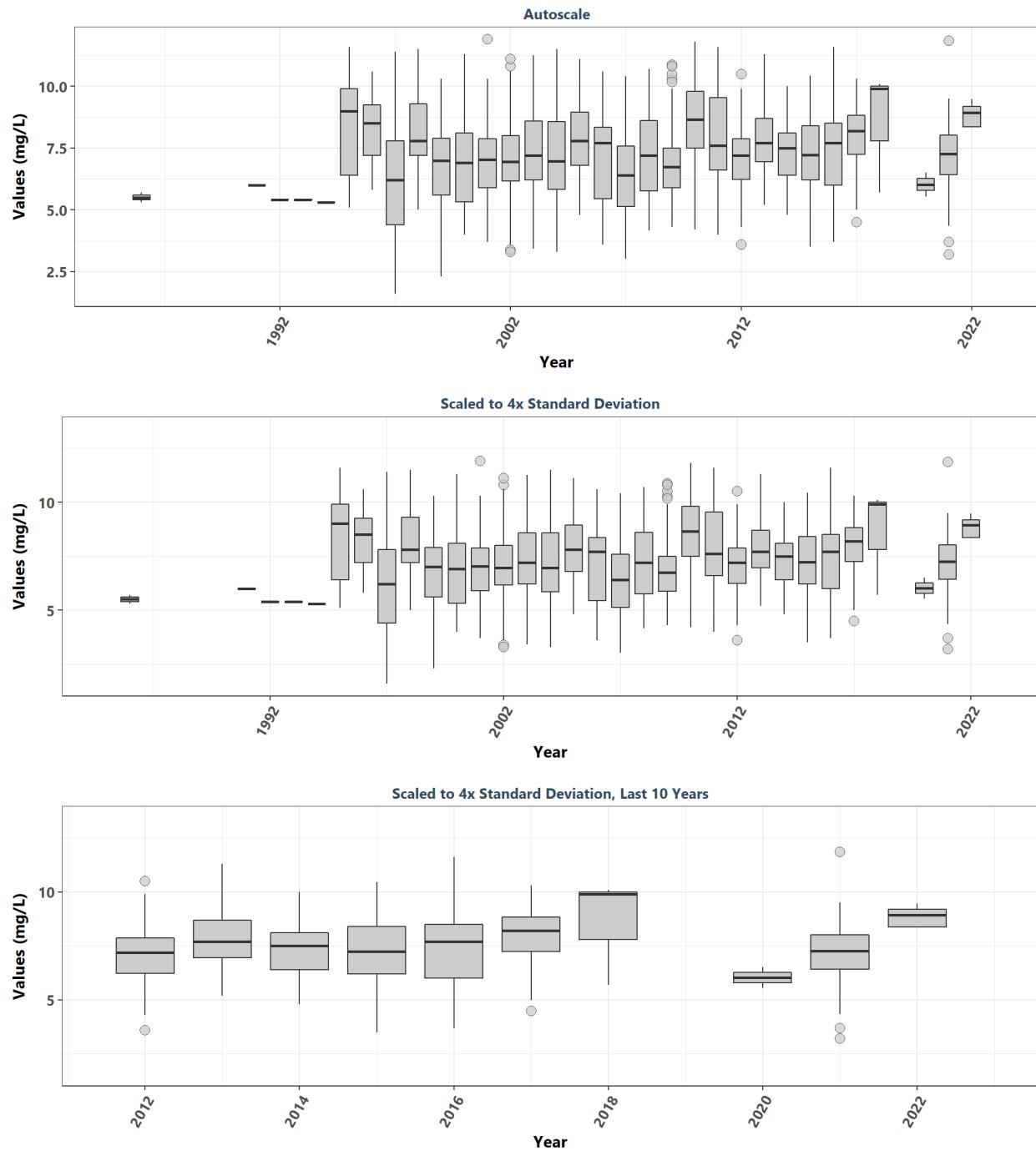
Nassau River-St. Johns River Marshes Aquatic Preserve
By Year & Month



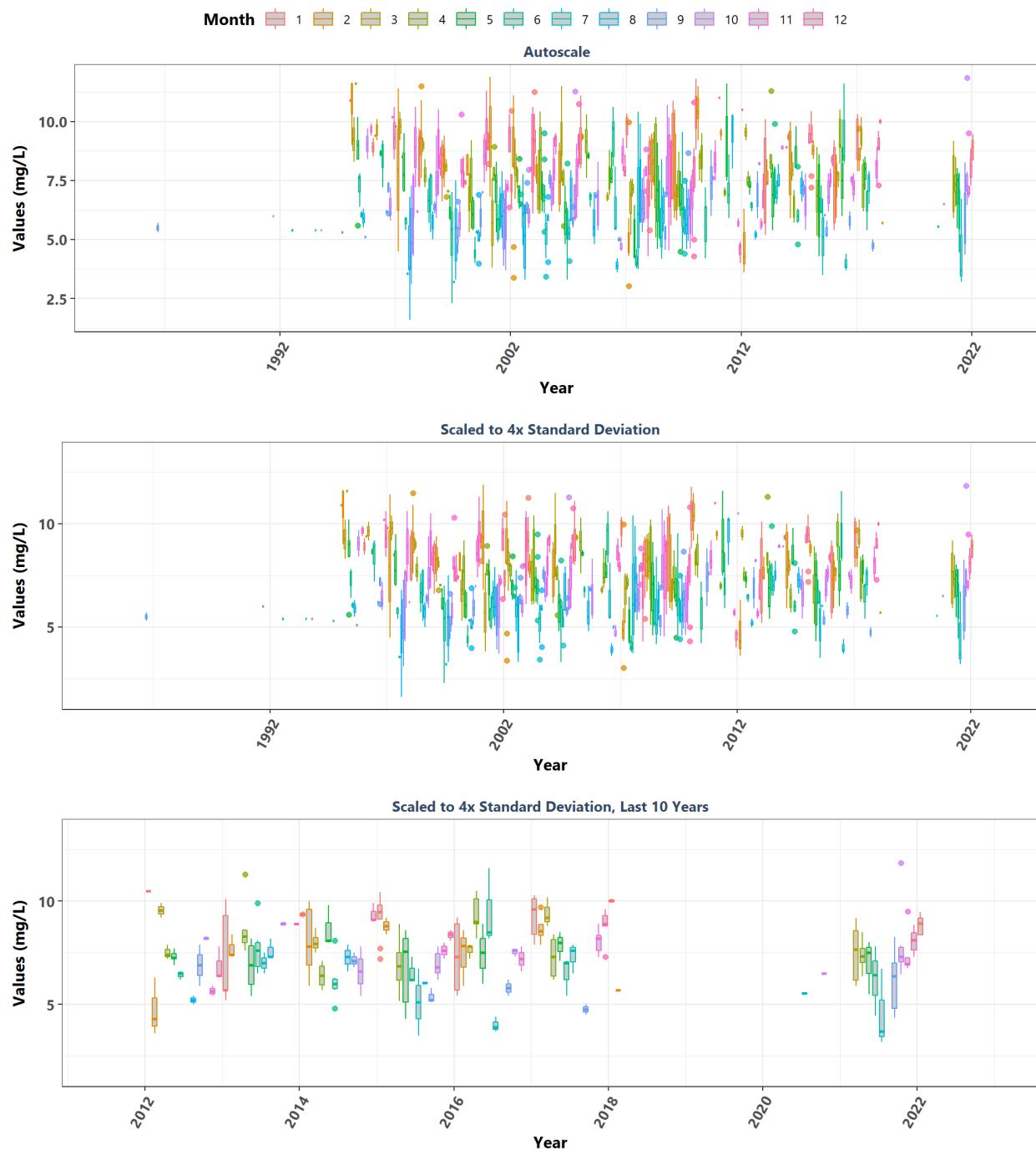
Nassau River-St. Johns River Marshes Aquatic Preserve
By Month



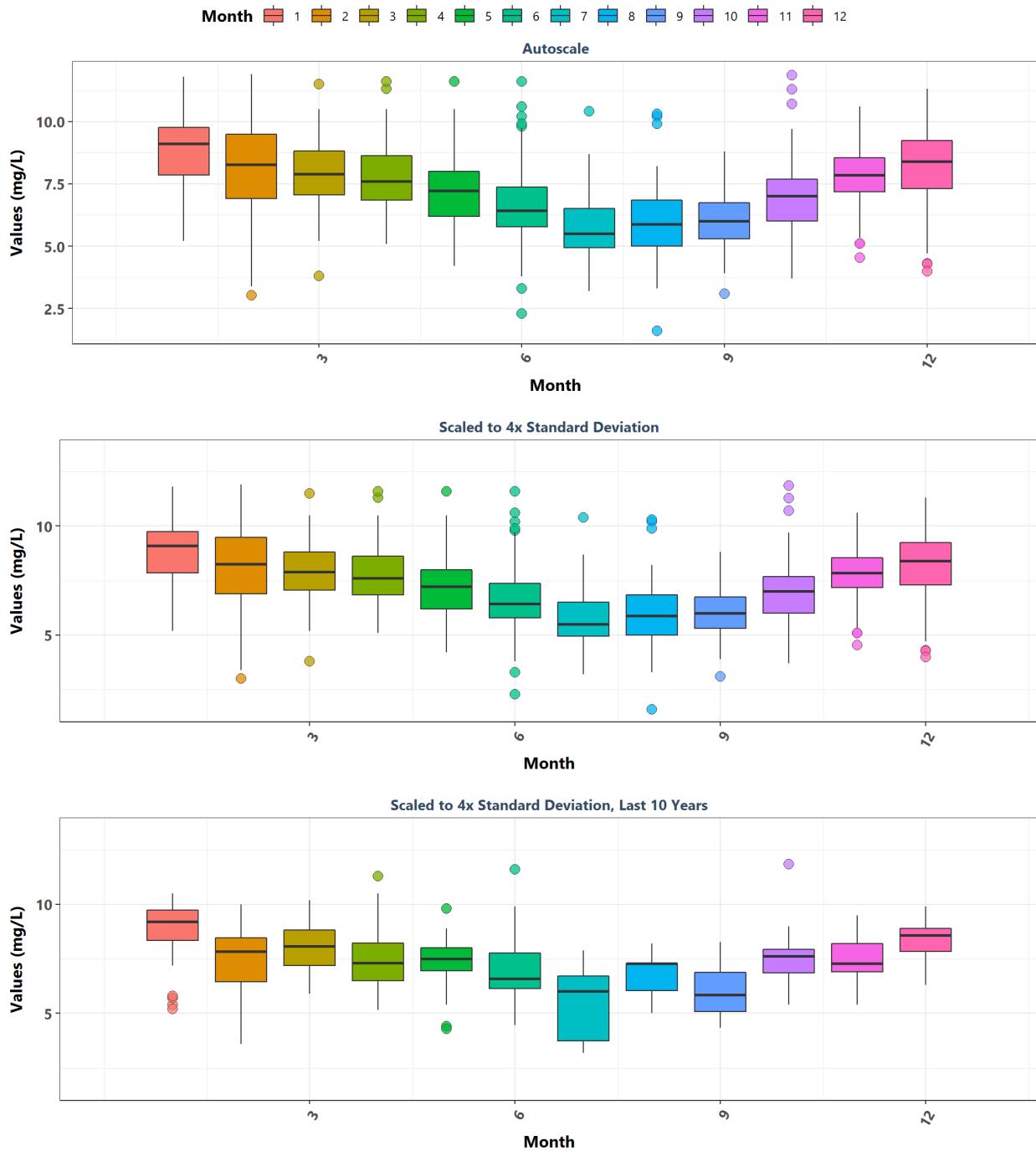
Nature Coast Aquatic Preserve
By Year



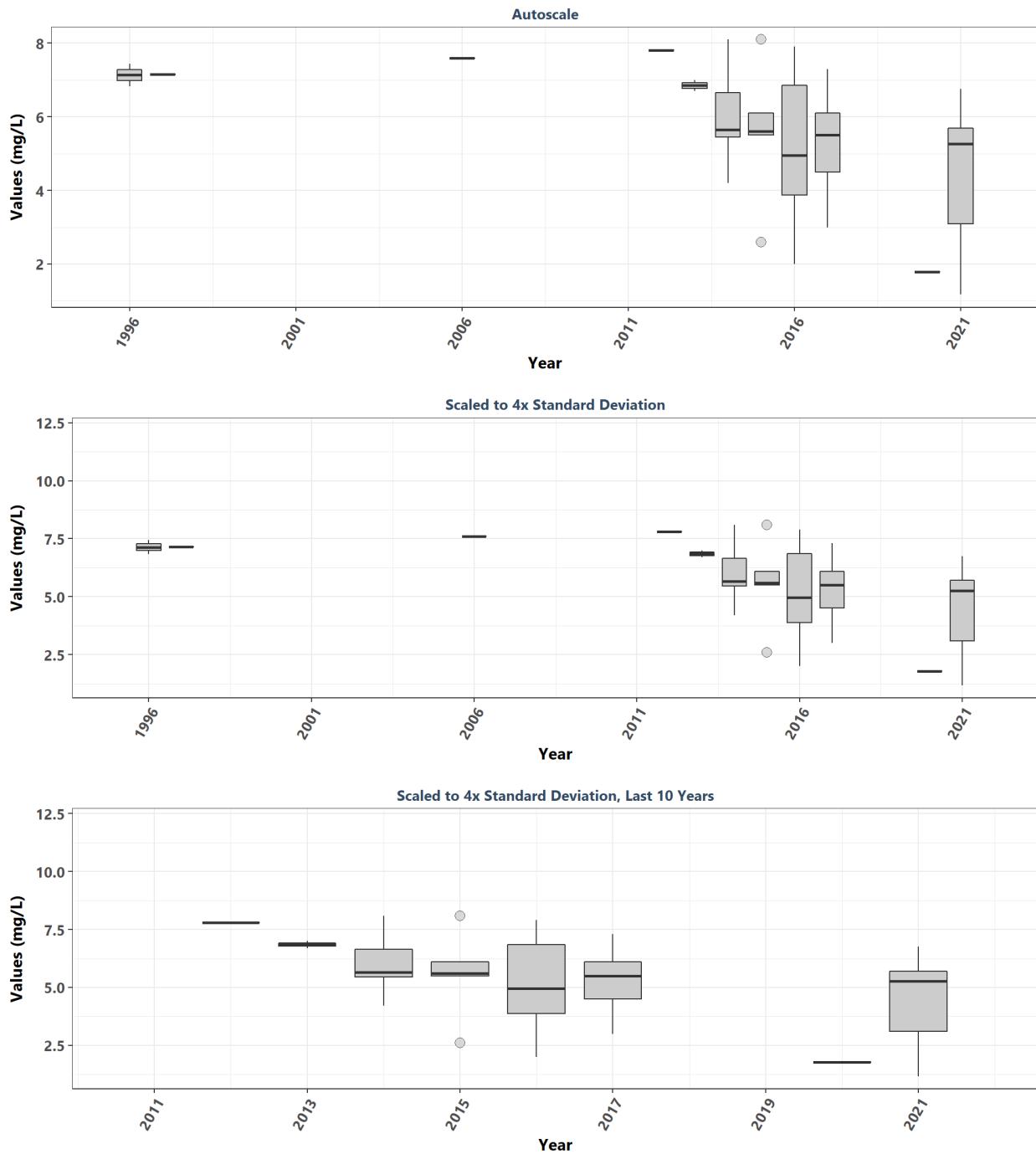
Nature Coast Aquatic Preserve
By Year & Month



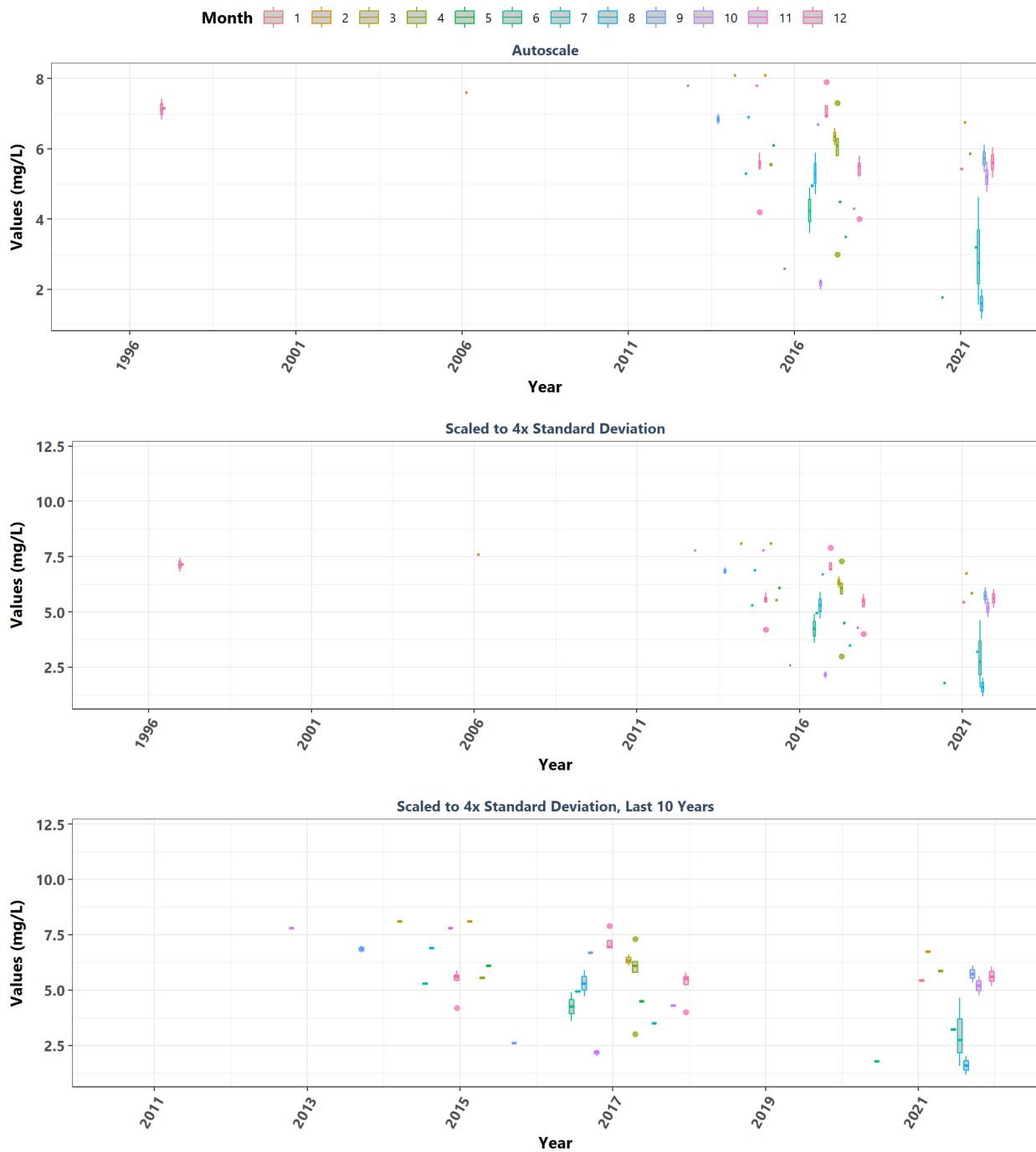
Nature Coast Aquatic Preserve
By Month



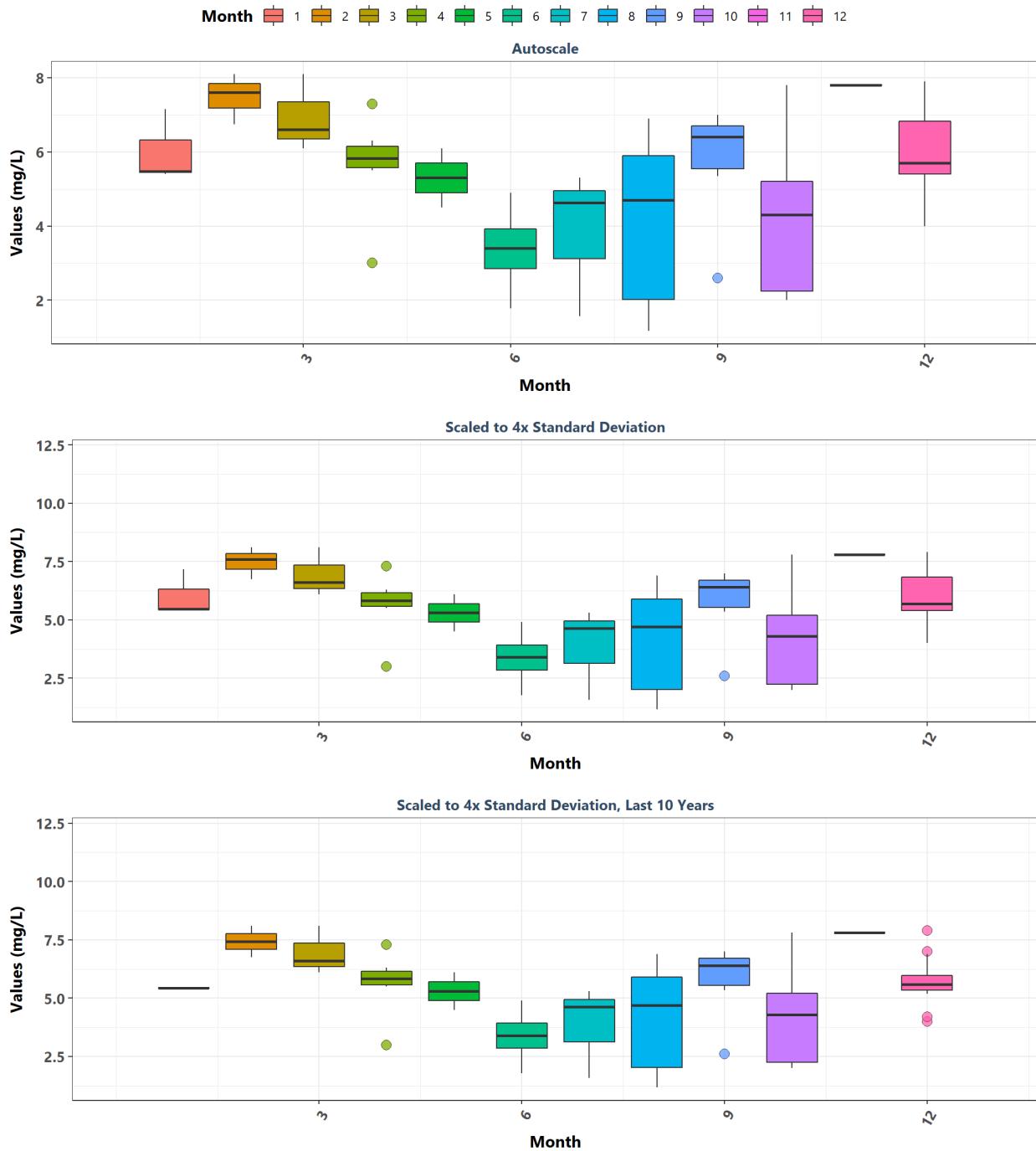
North Fork St. Lucie Aquatic Preserve
By Year



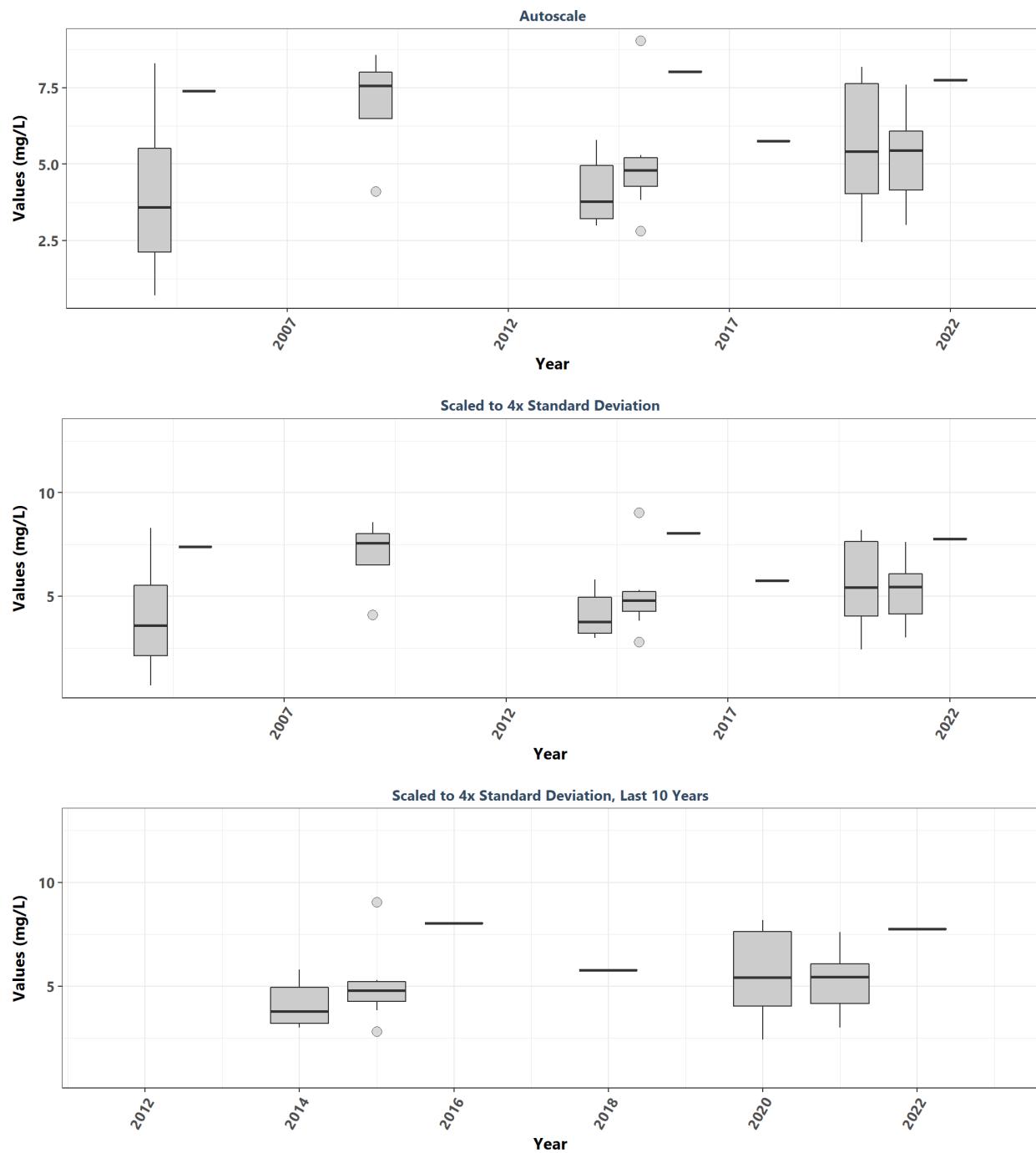
North Fork St. Lucie Aquatic Preserve
By Year & Month



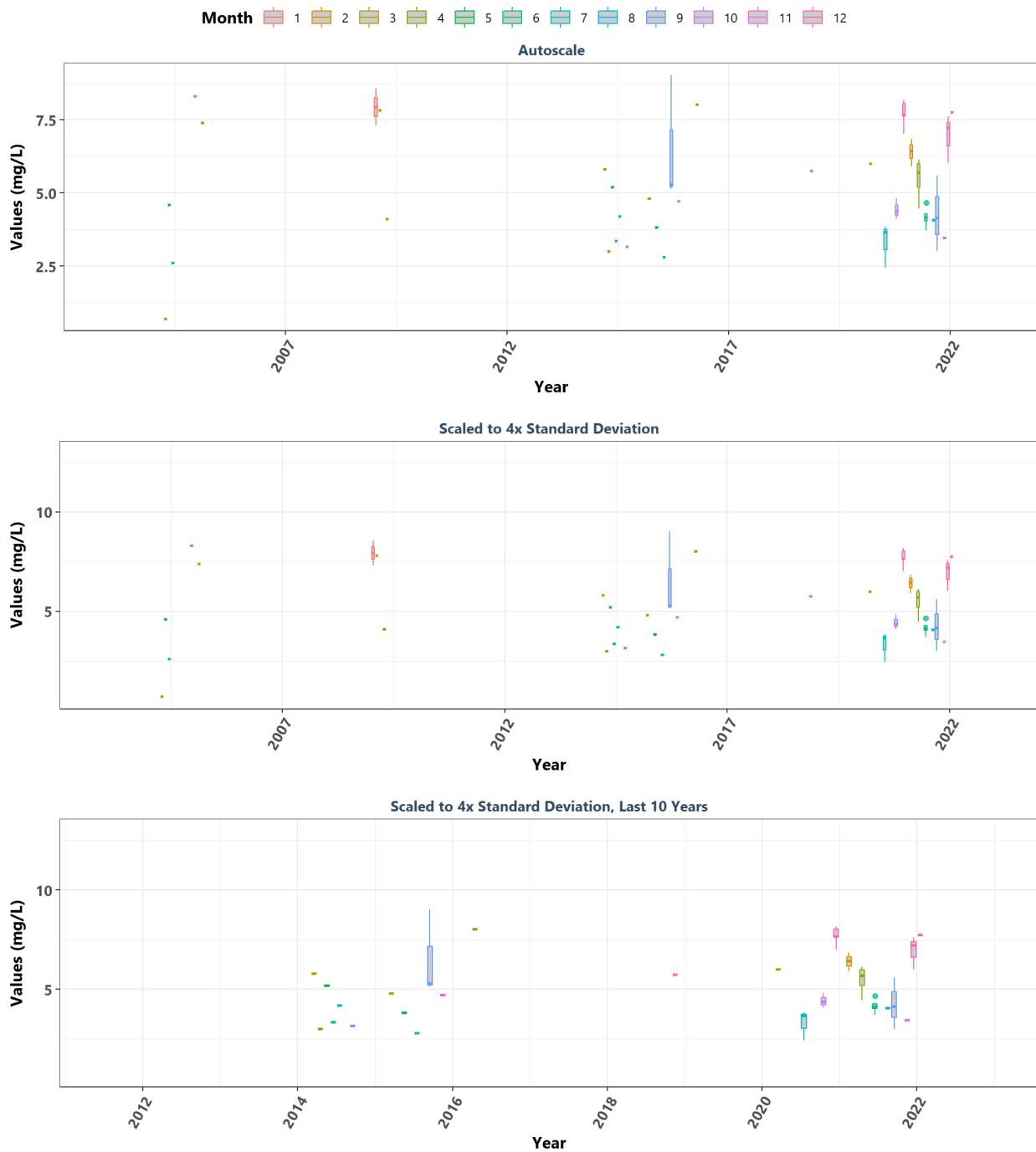
North Fork St. Lucie Aquatic Preserve
By Month



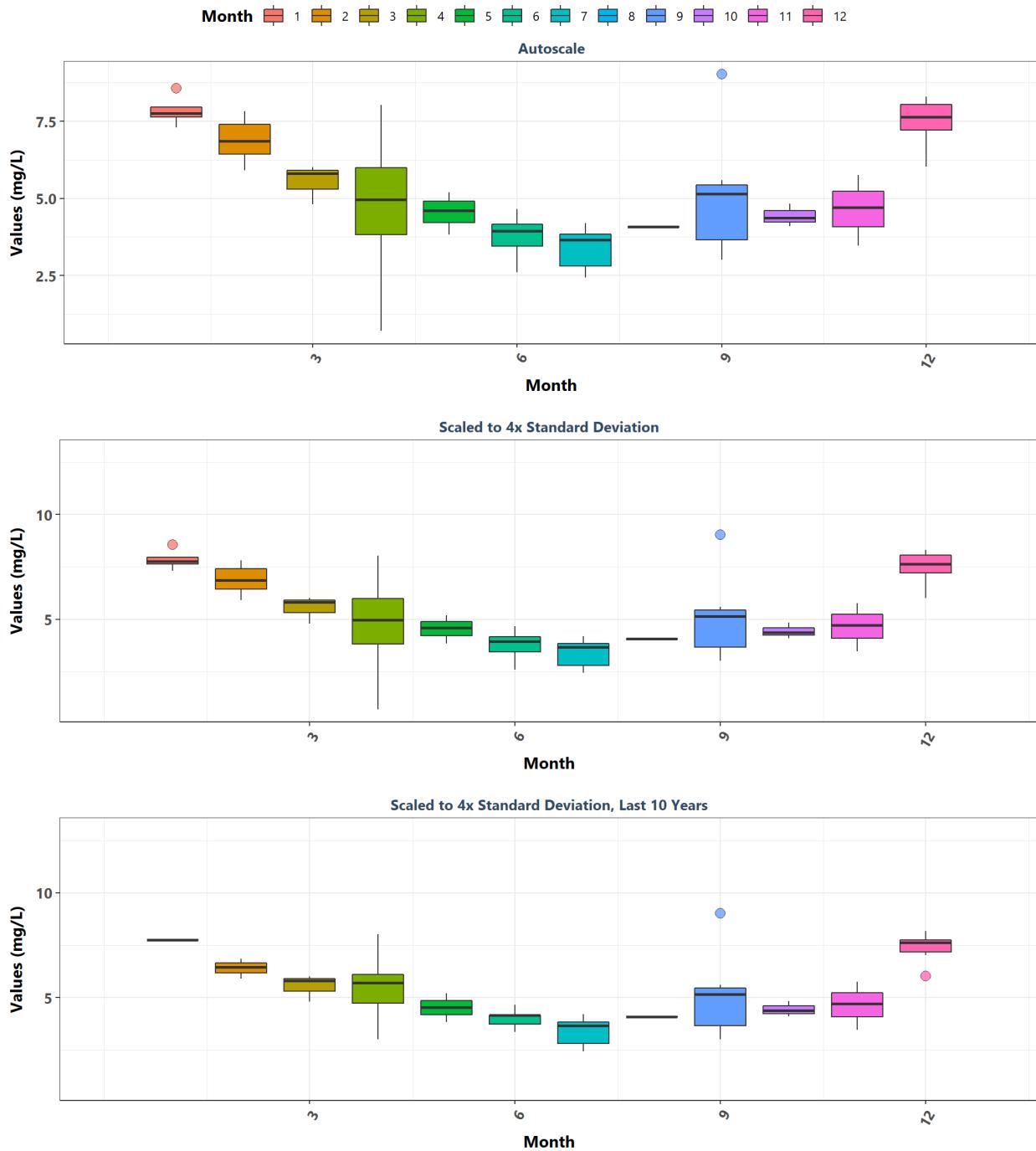
Pellicer Creek Aquatic Preserve
By Year



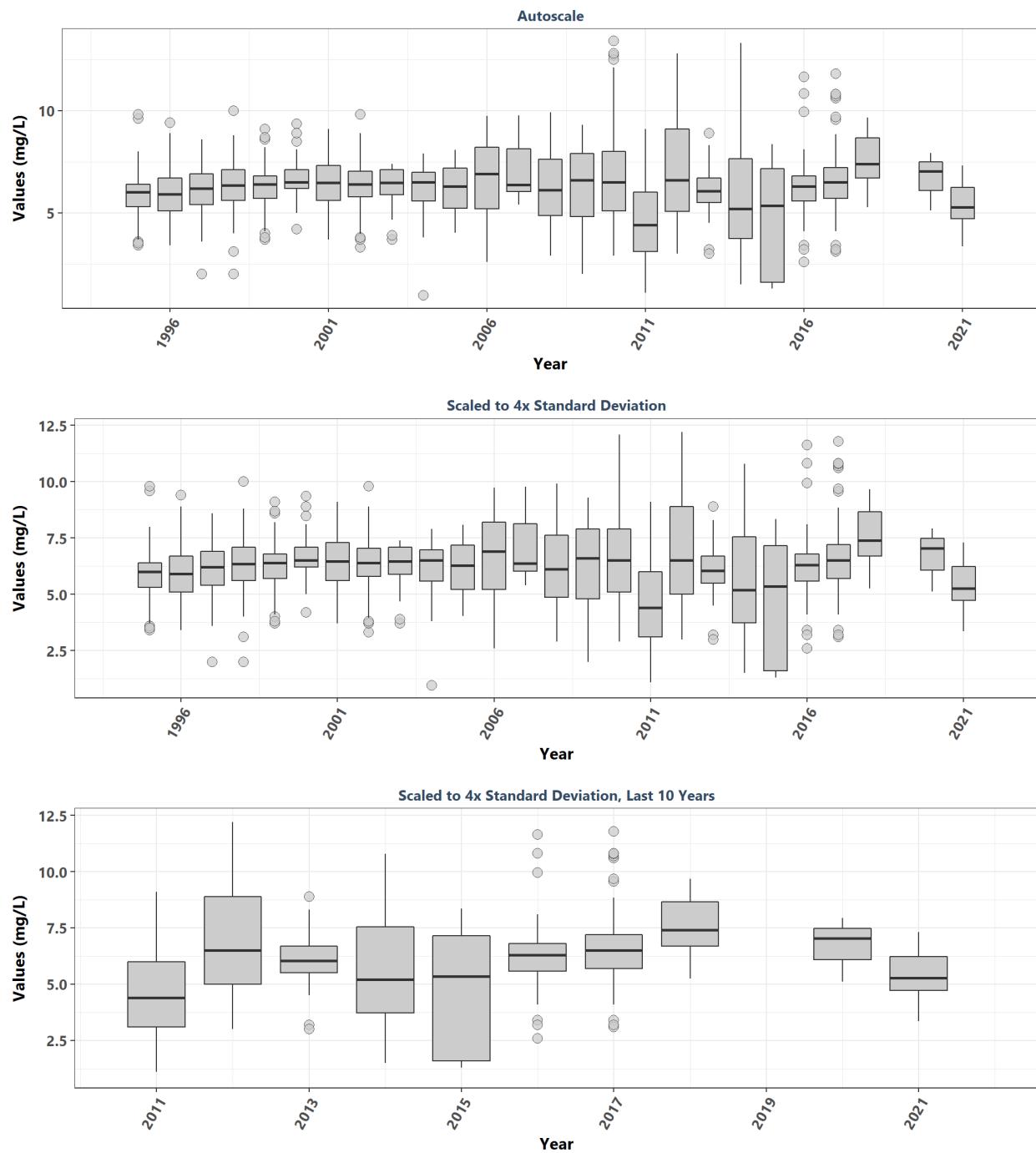
Pellicer Creek Aquatic Preserve
By Year & Month



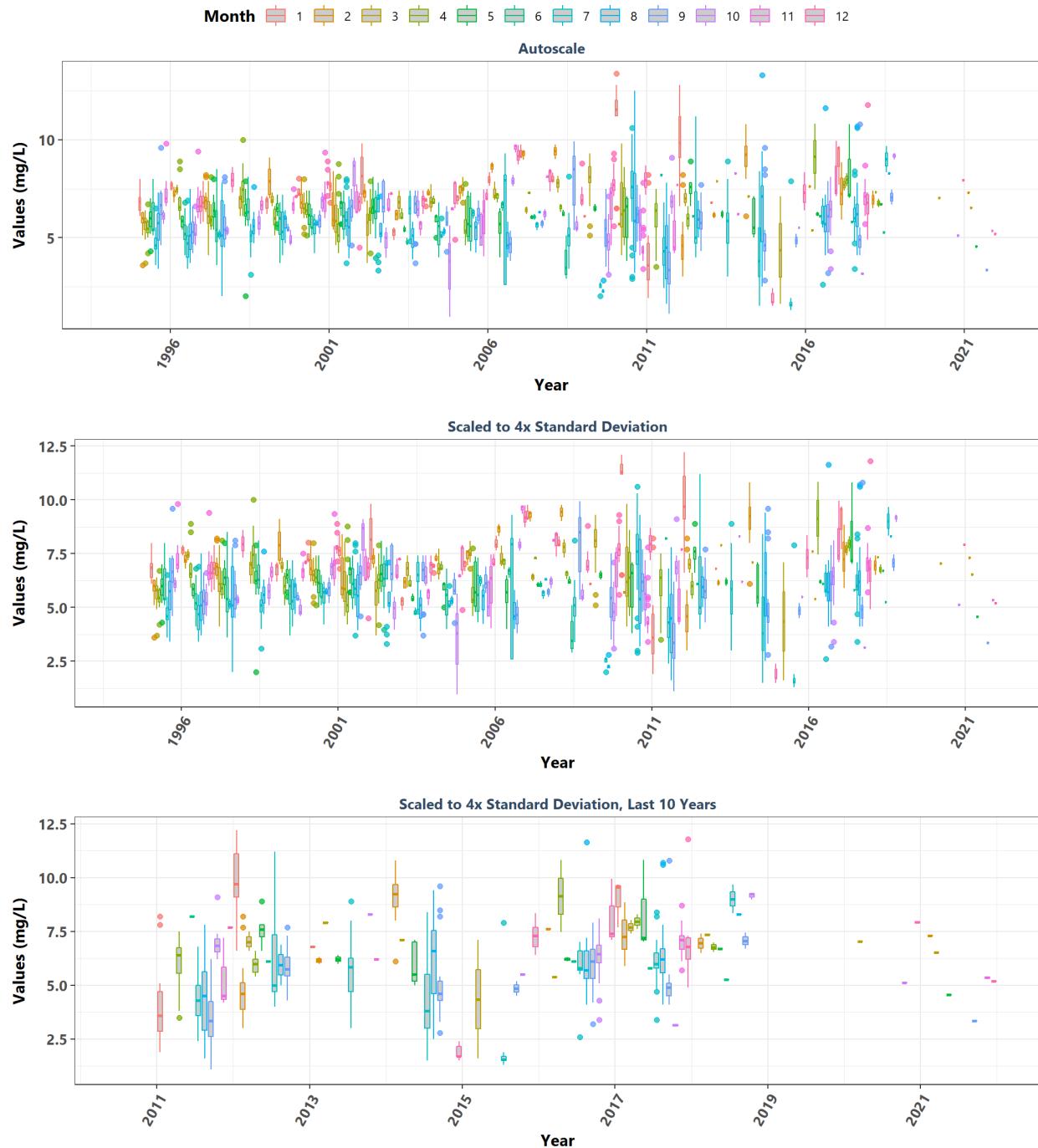
Pellicer Creek Aquatic Preserve
By Month



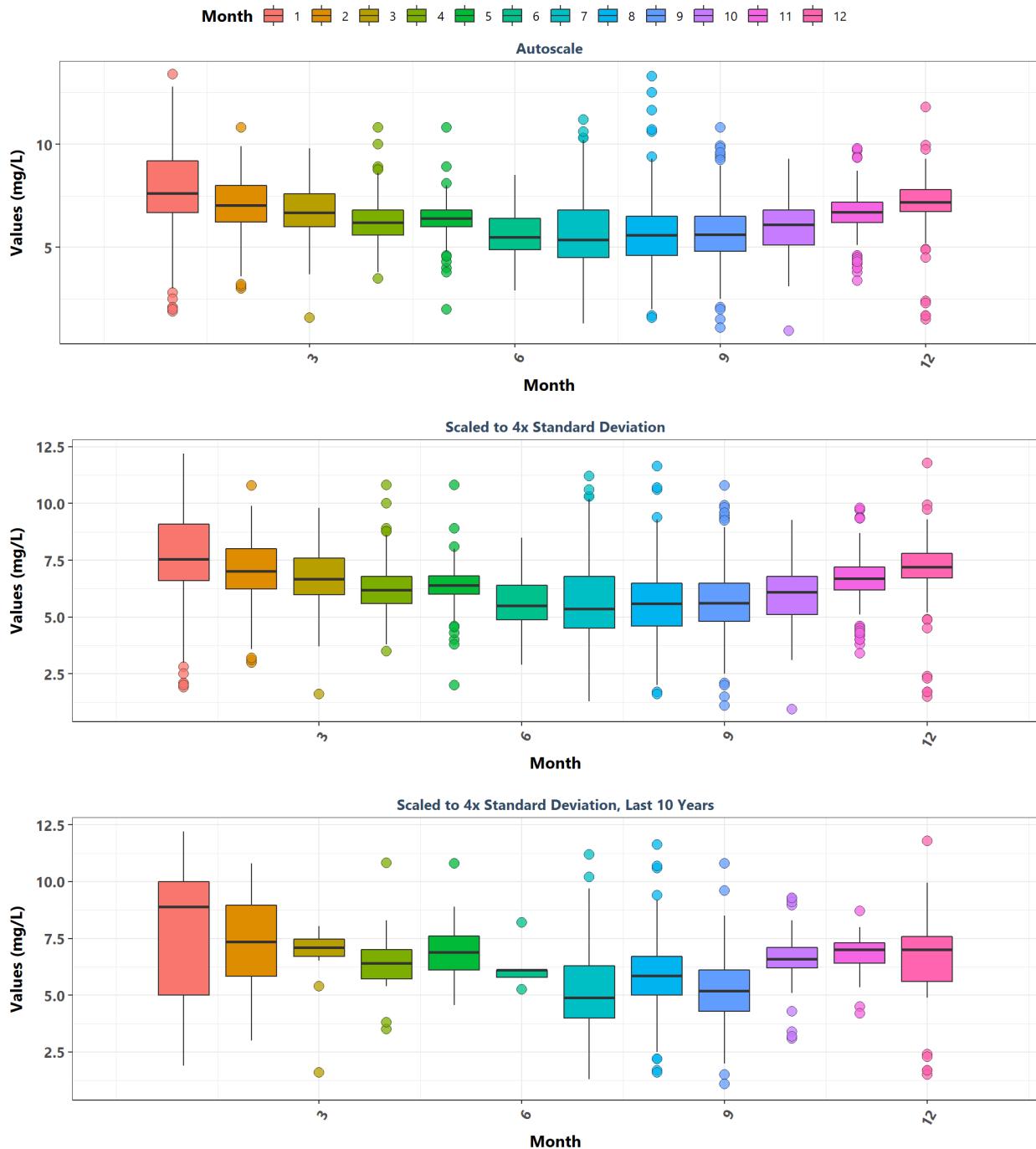
Pine Island Sound Aquatic Preserve
By Year



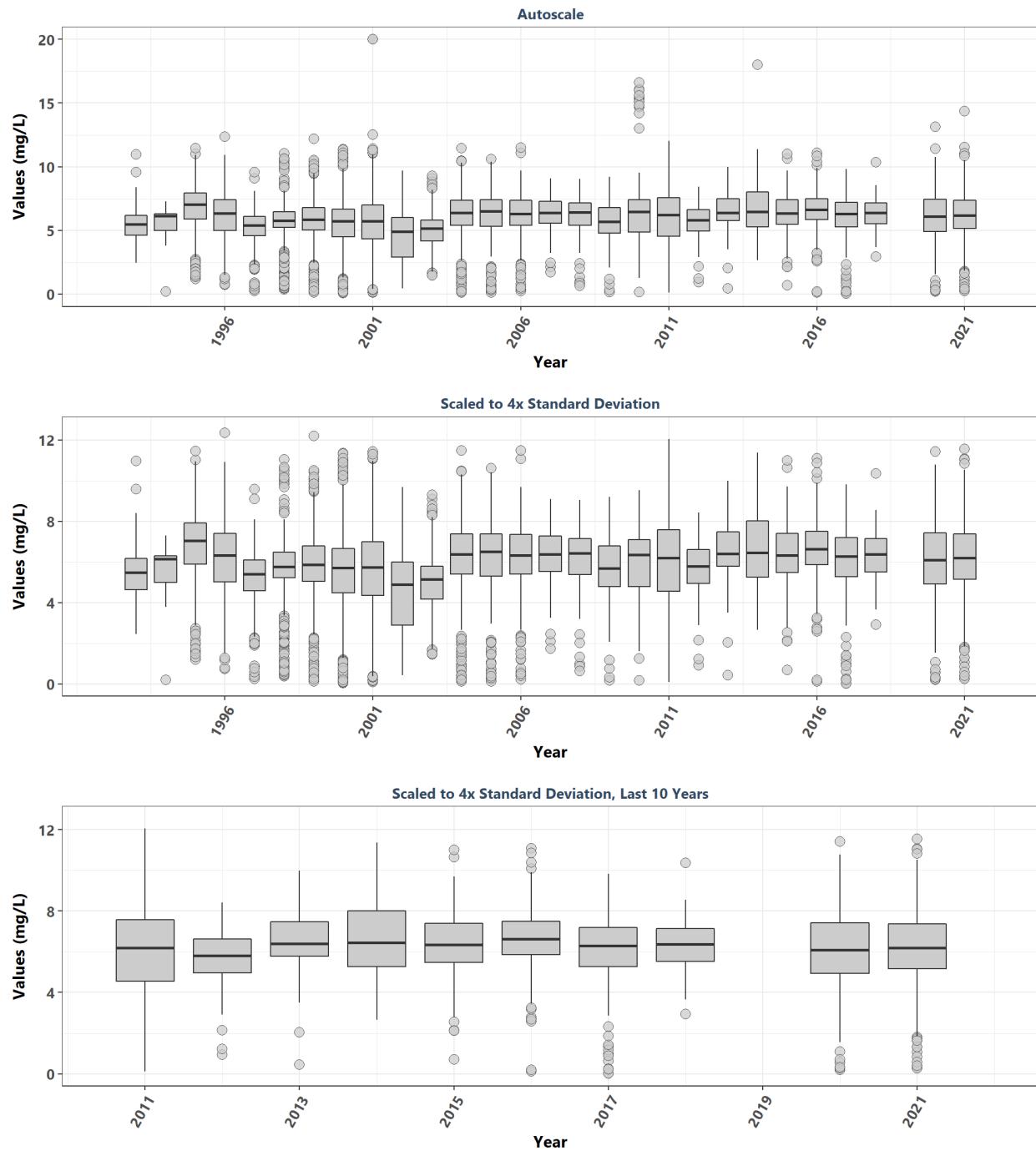
Pine Island Sound Aquatic Preserve
By Year & Month



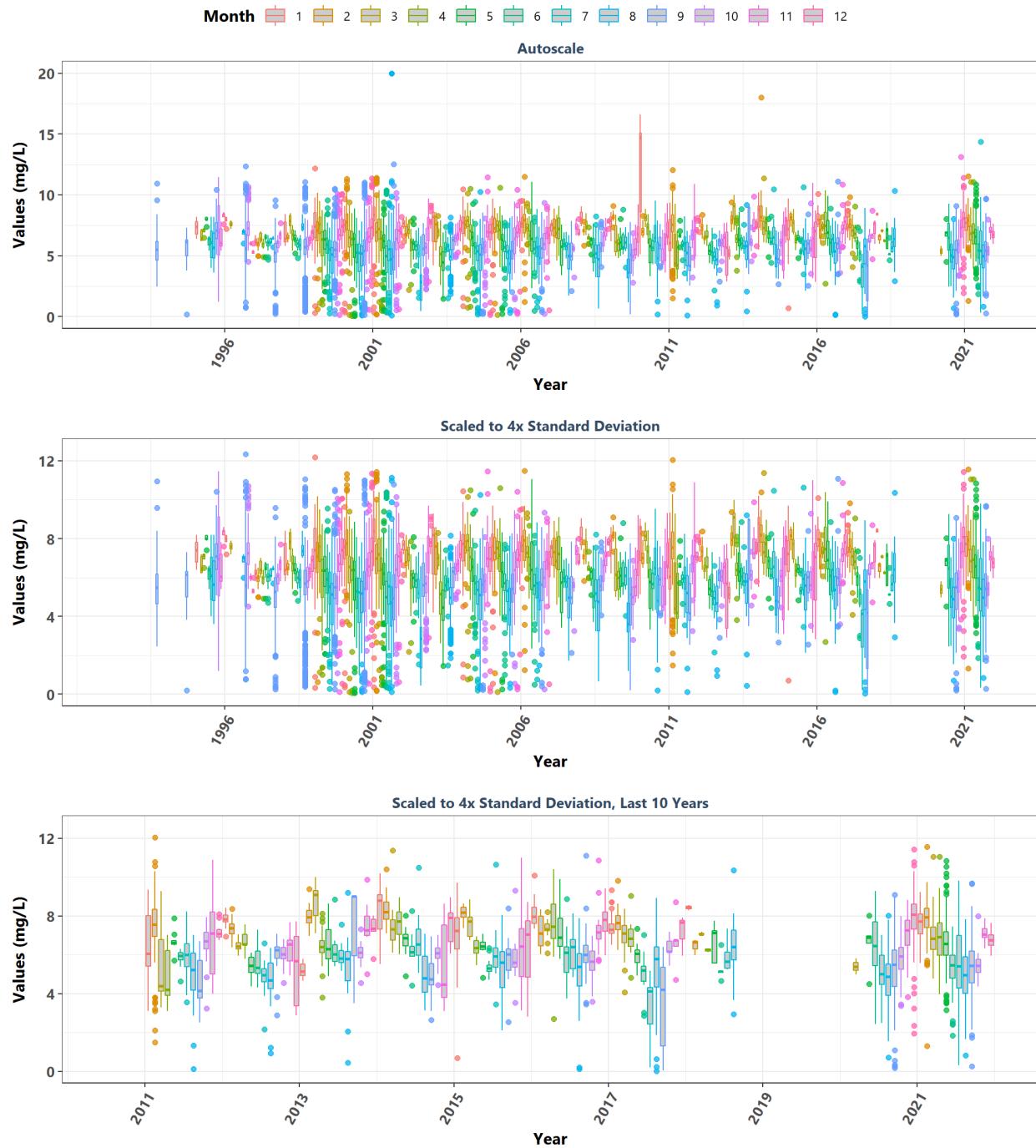
Pine Island Sound Aquatic Preserve
By Month



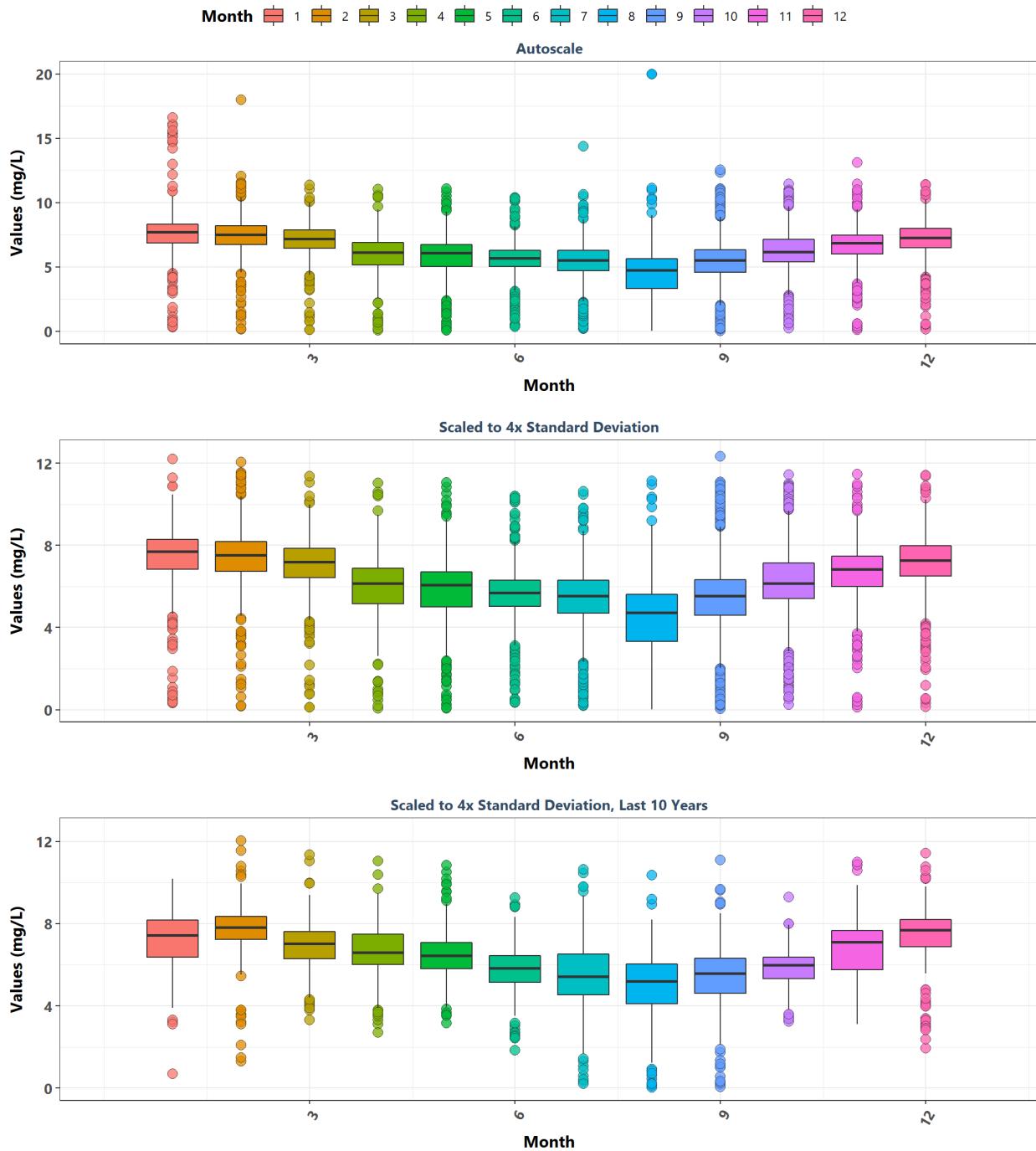
Pinellas County Aquatic Preserve
By Year



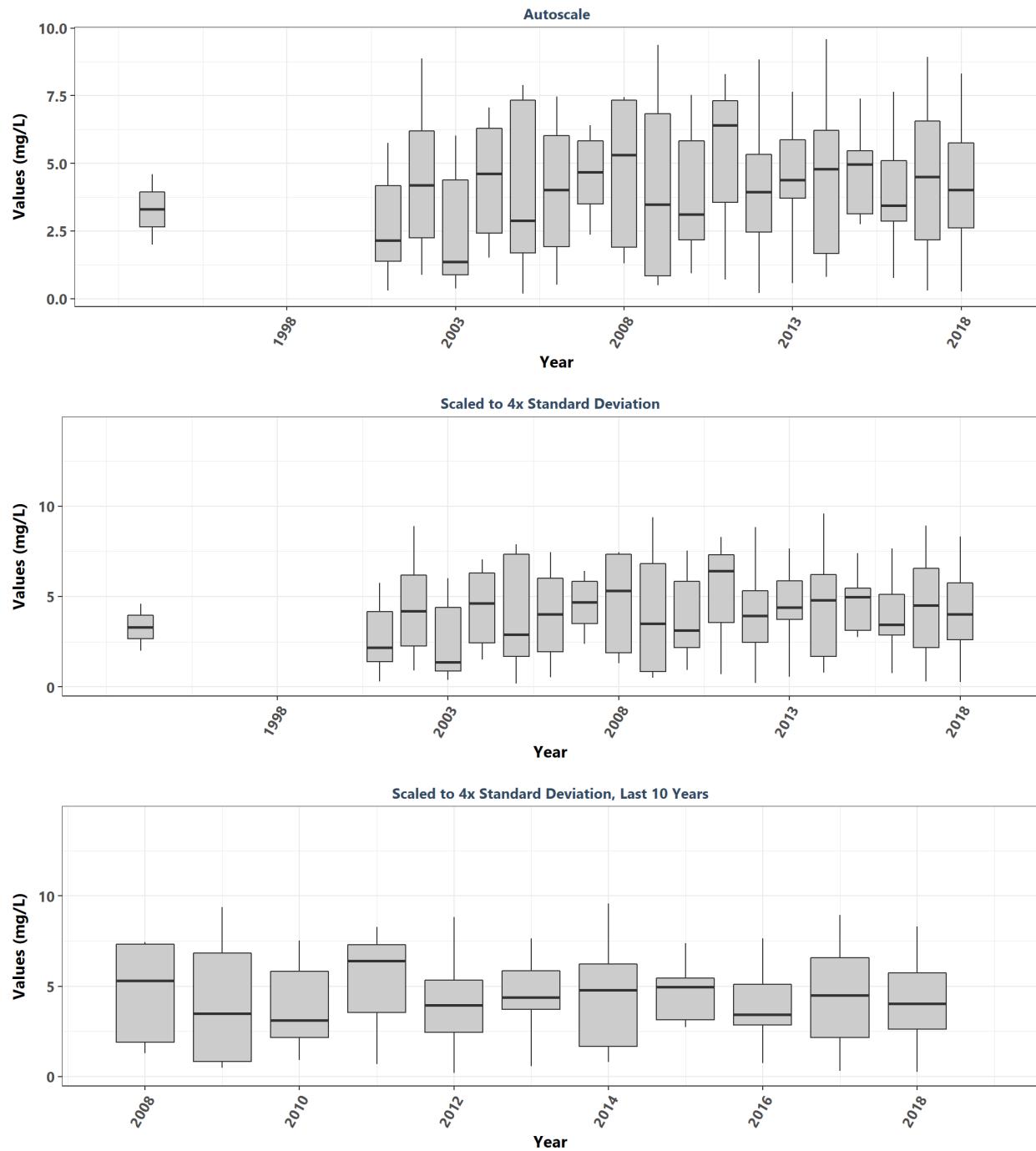
Pinellas County Aquatic Preserve
By Year & Month



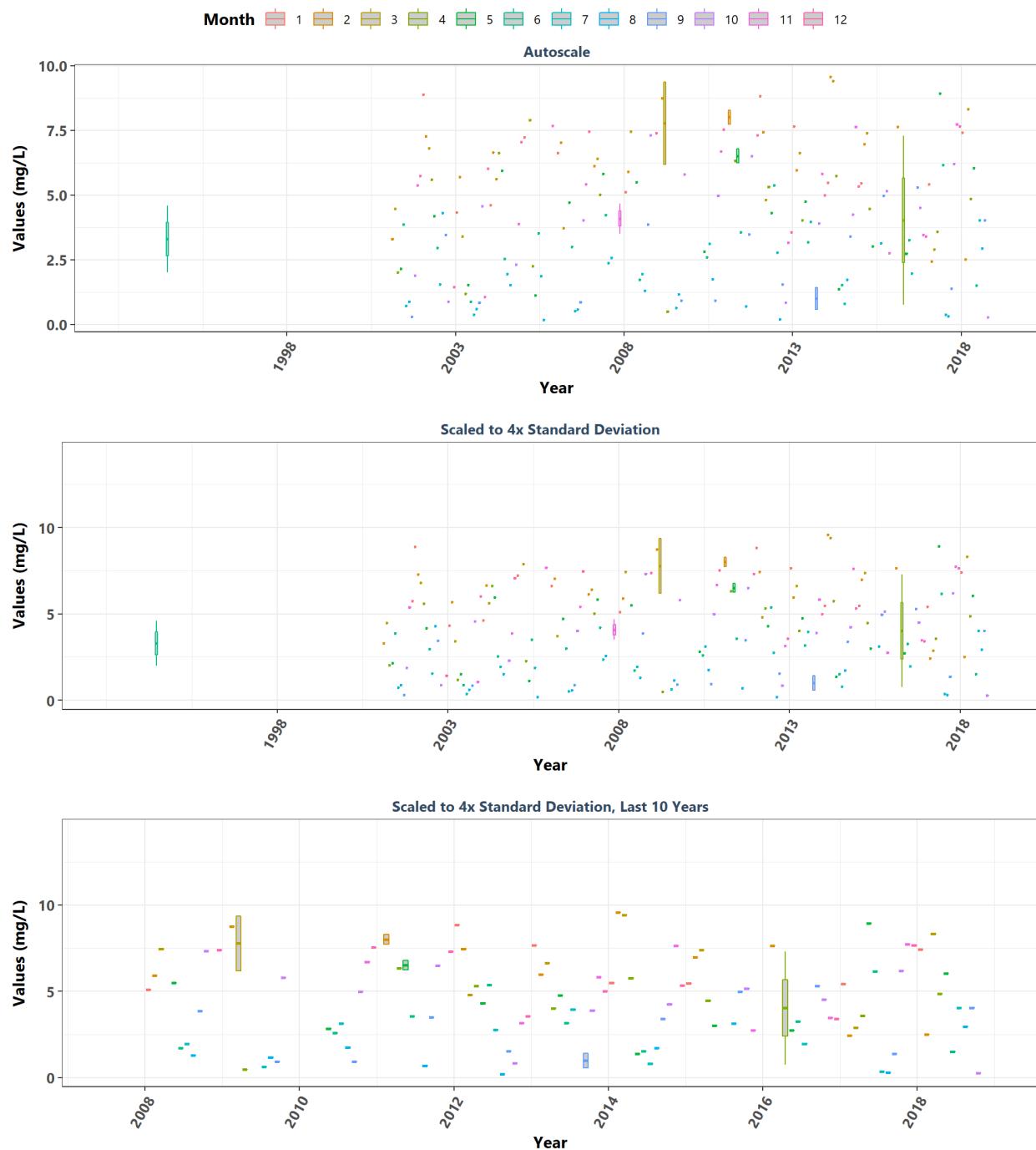
Pinellas County Aquatic Preserve
By Month



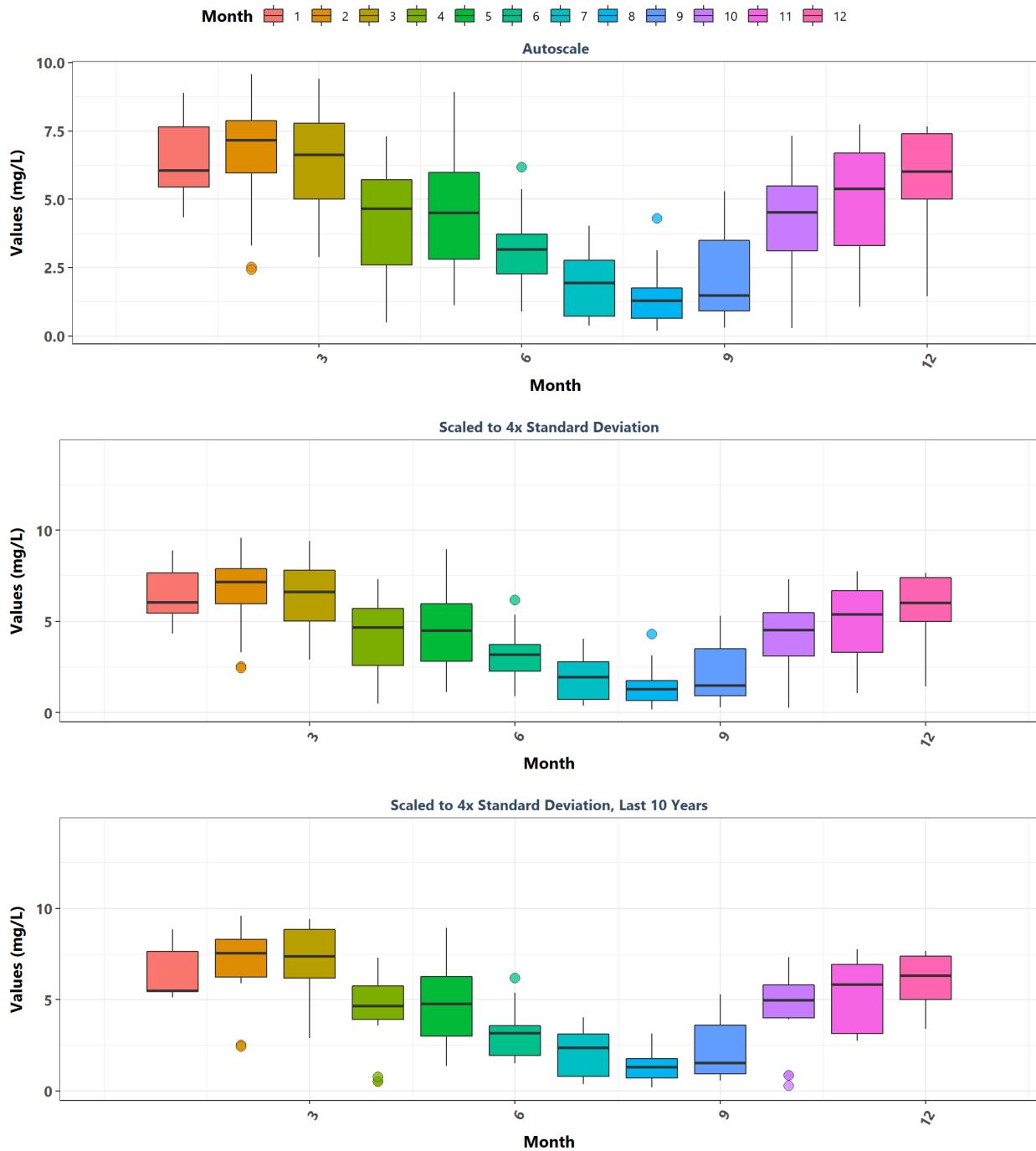
Rocky Bayou State Park Aquatic Preserve
By Year



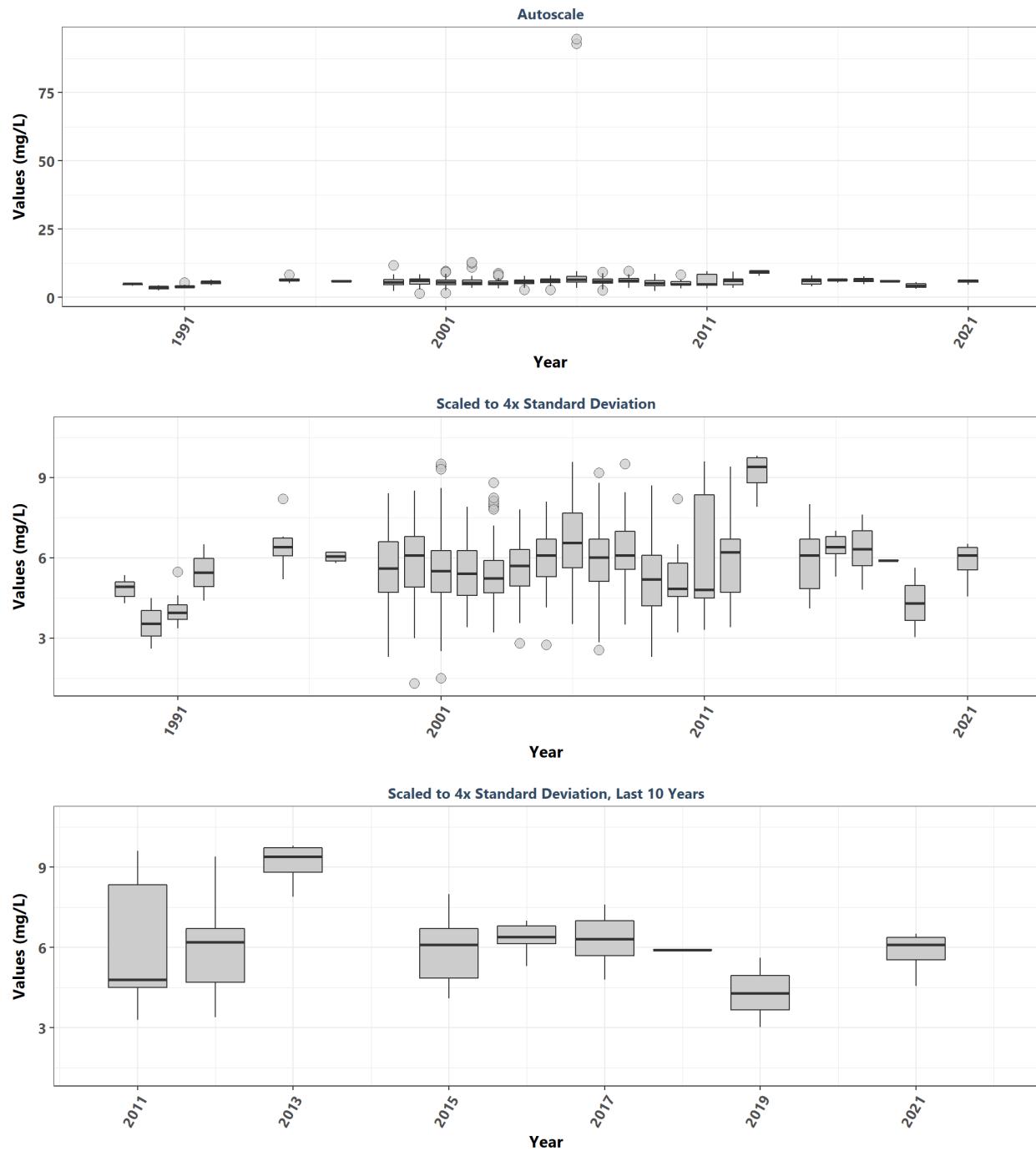
Rocky Bayou State Park Aquatic Preserve
By Year & Month



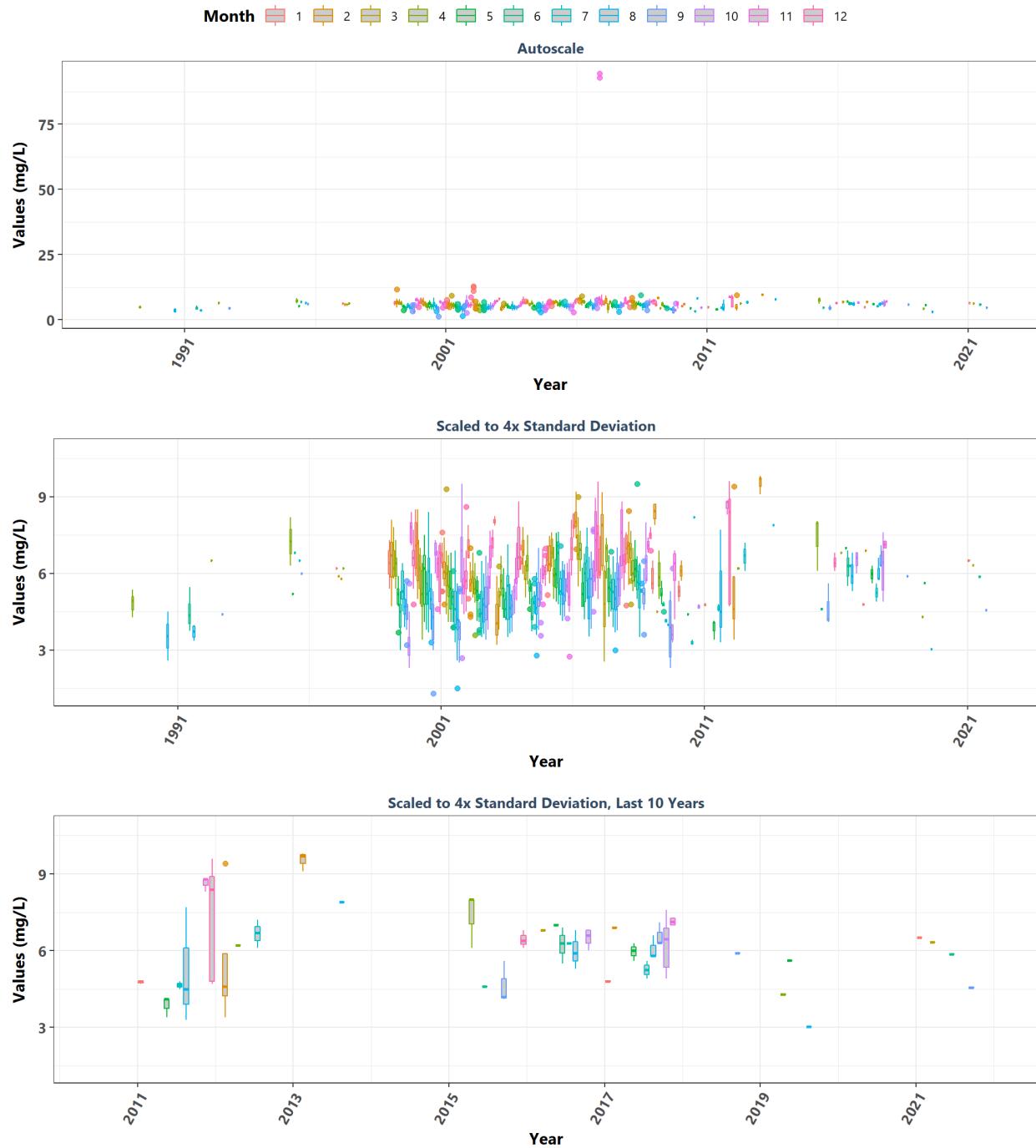
Rocky Bayou State Park Aquatic Preserve
By Month



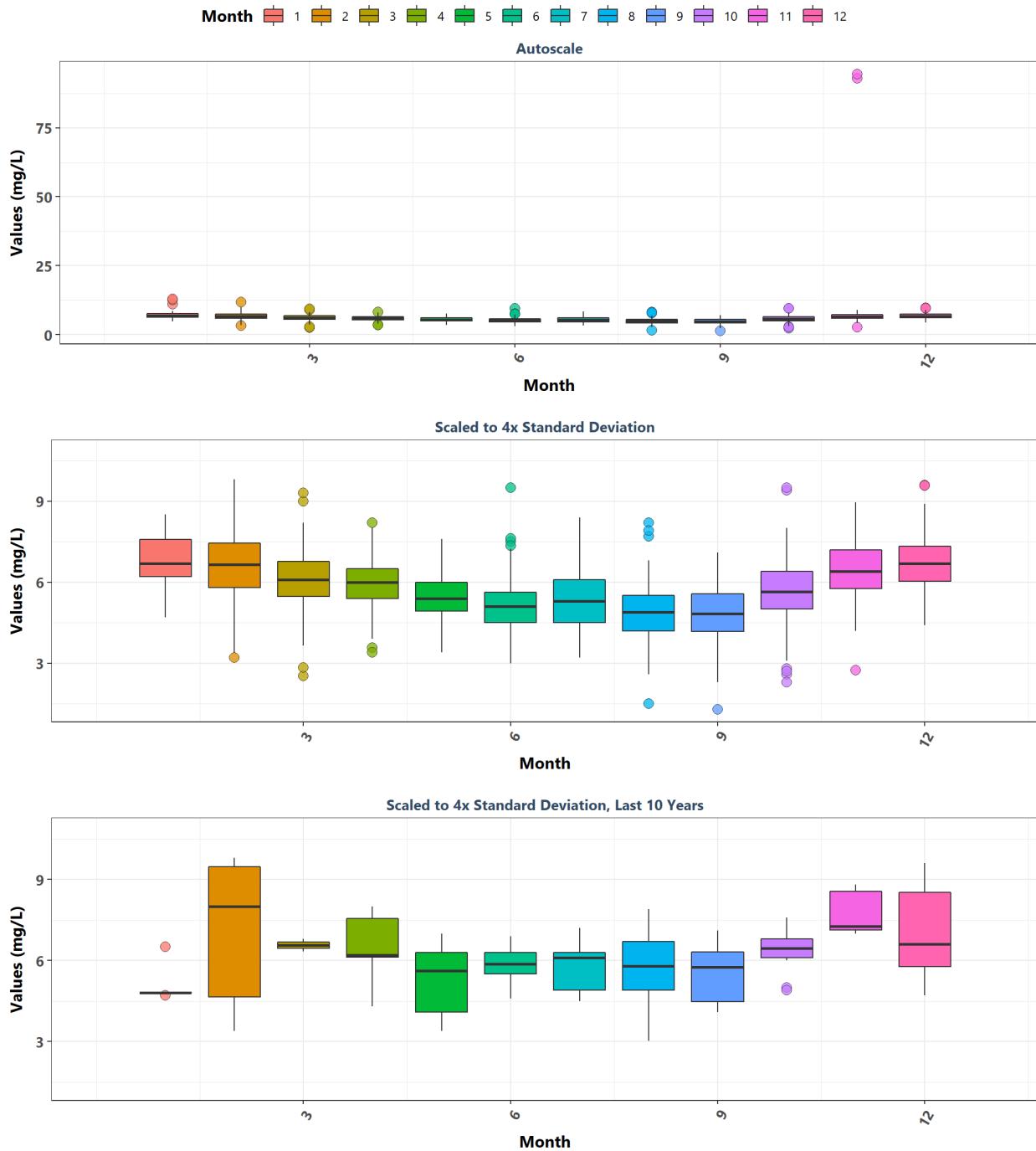
Rookery Bay Aquatic Preserve
By Year



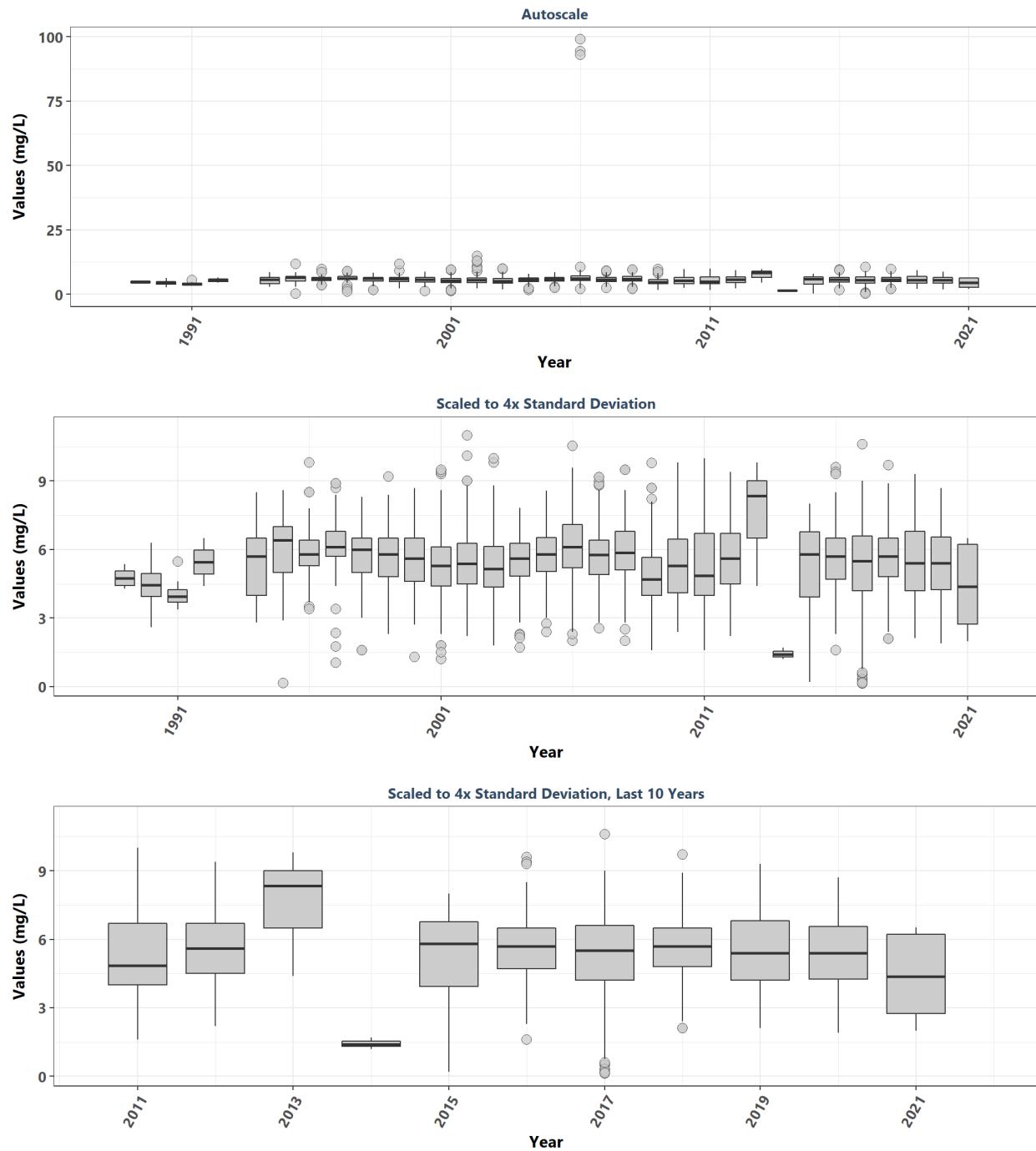
Rookery Bay Aquatic Preserve
By Year & Month



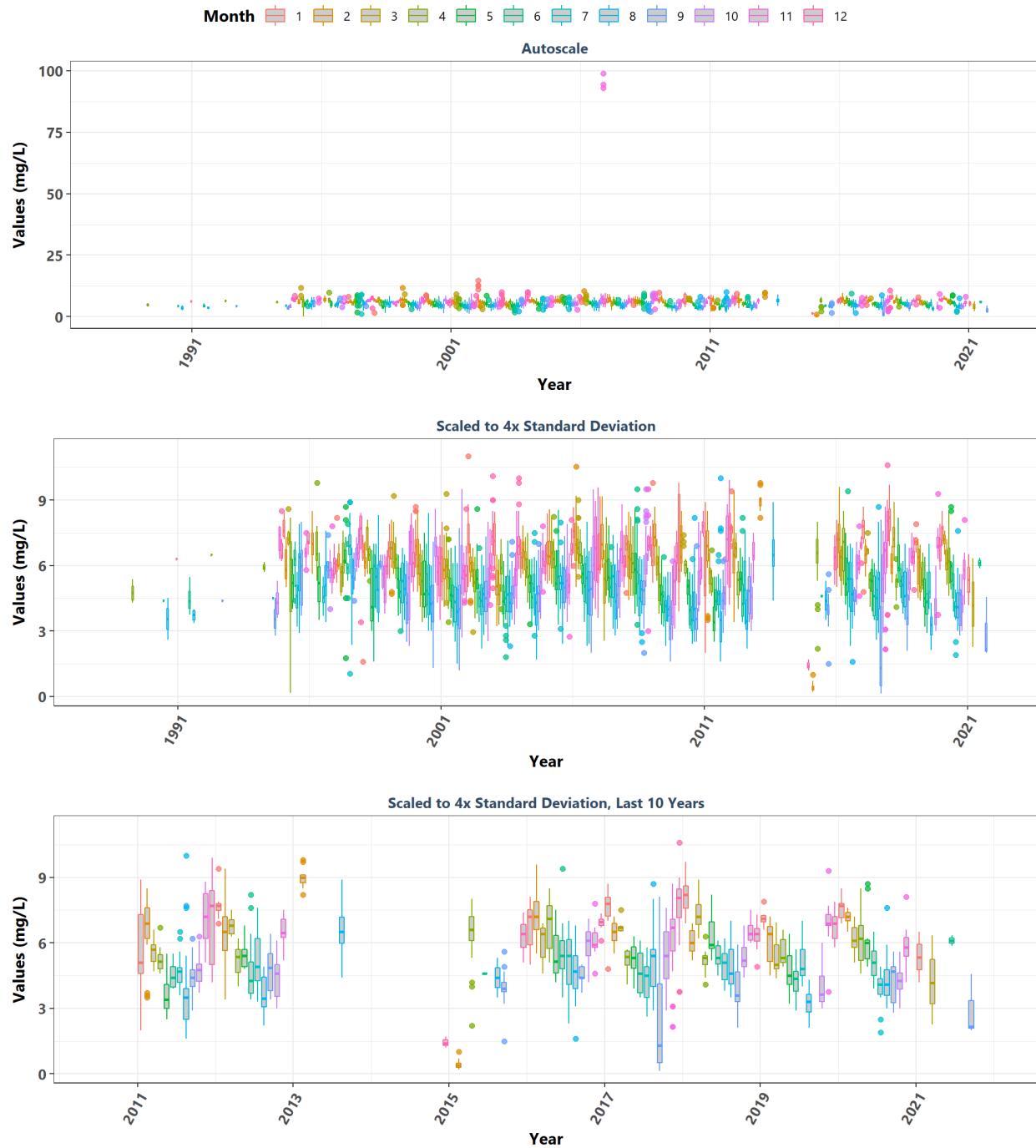
Rookery Bay Aquatic Preserve
By Month



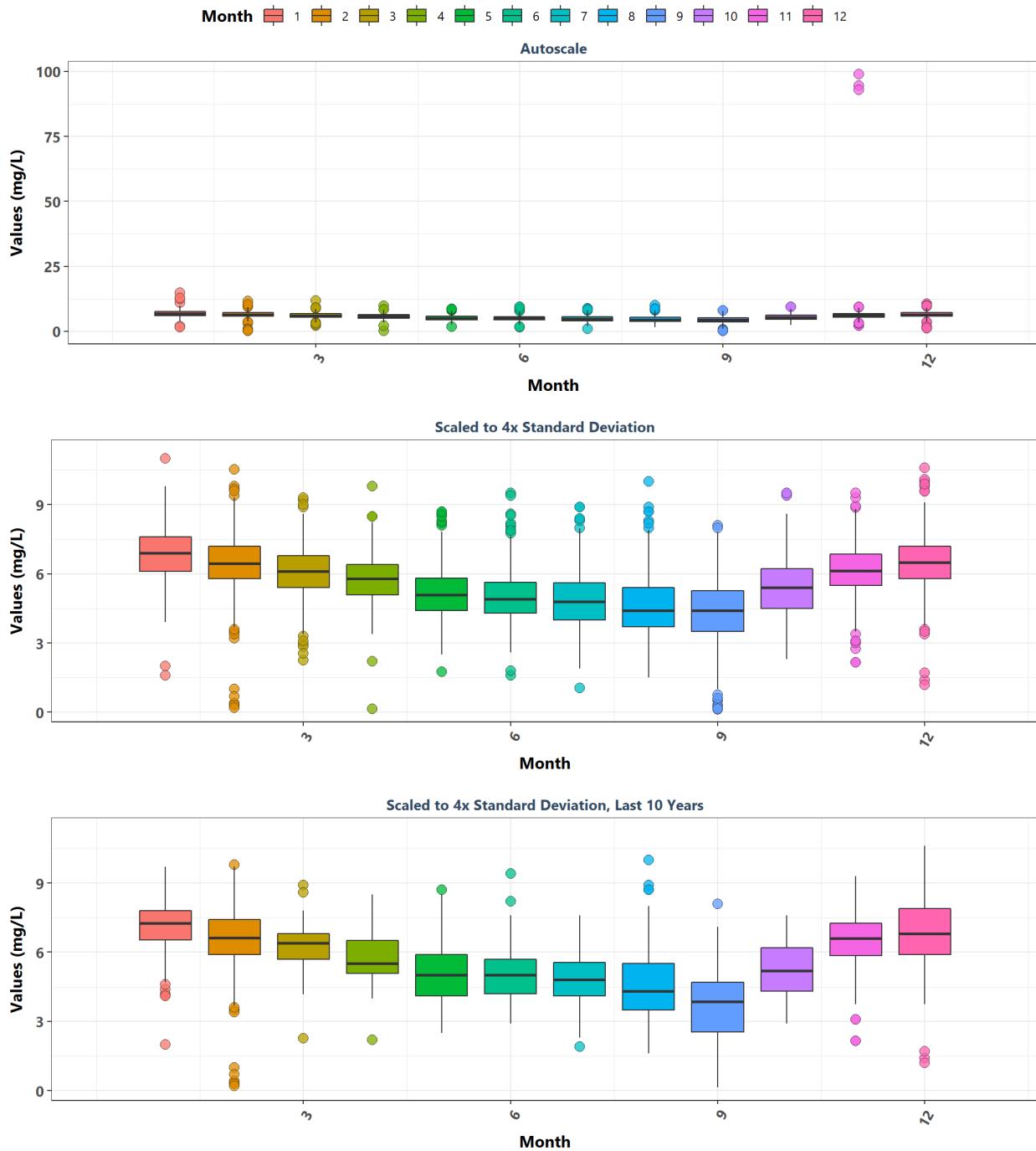
Rookery Bay National Estuarine Research Reserve
By Year



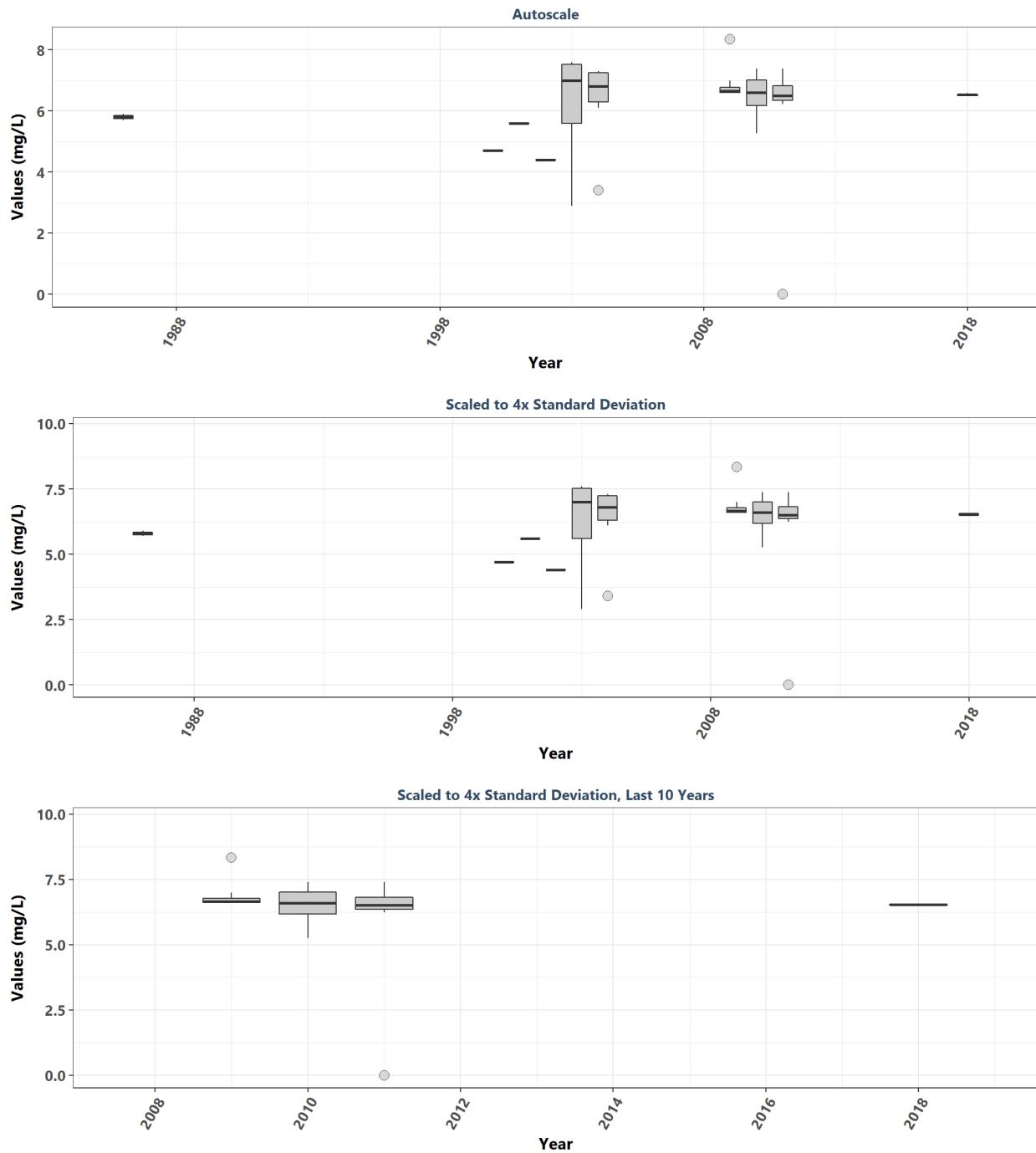
Rookery Bay National Estuarine Research Reserve
By Year & Month



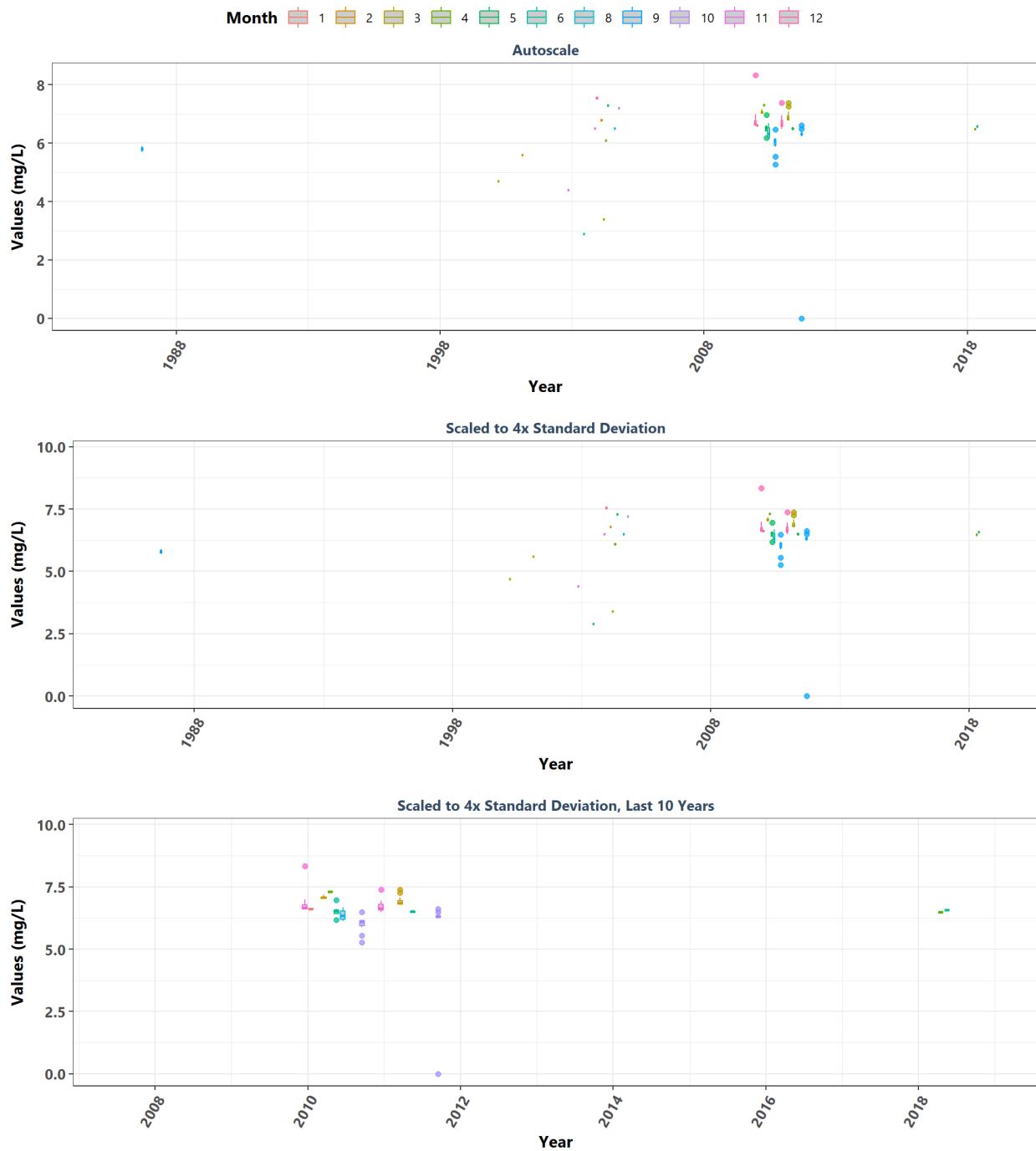
Rookery Bay National Estuarine Research Reserve
By Month



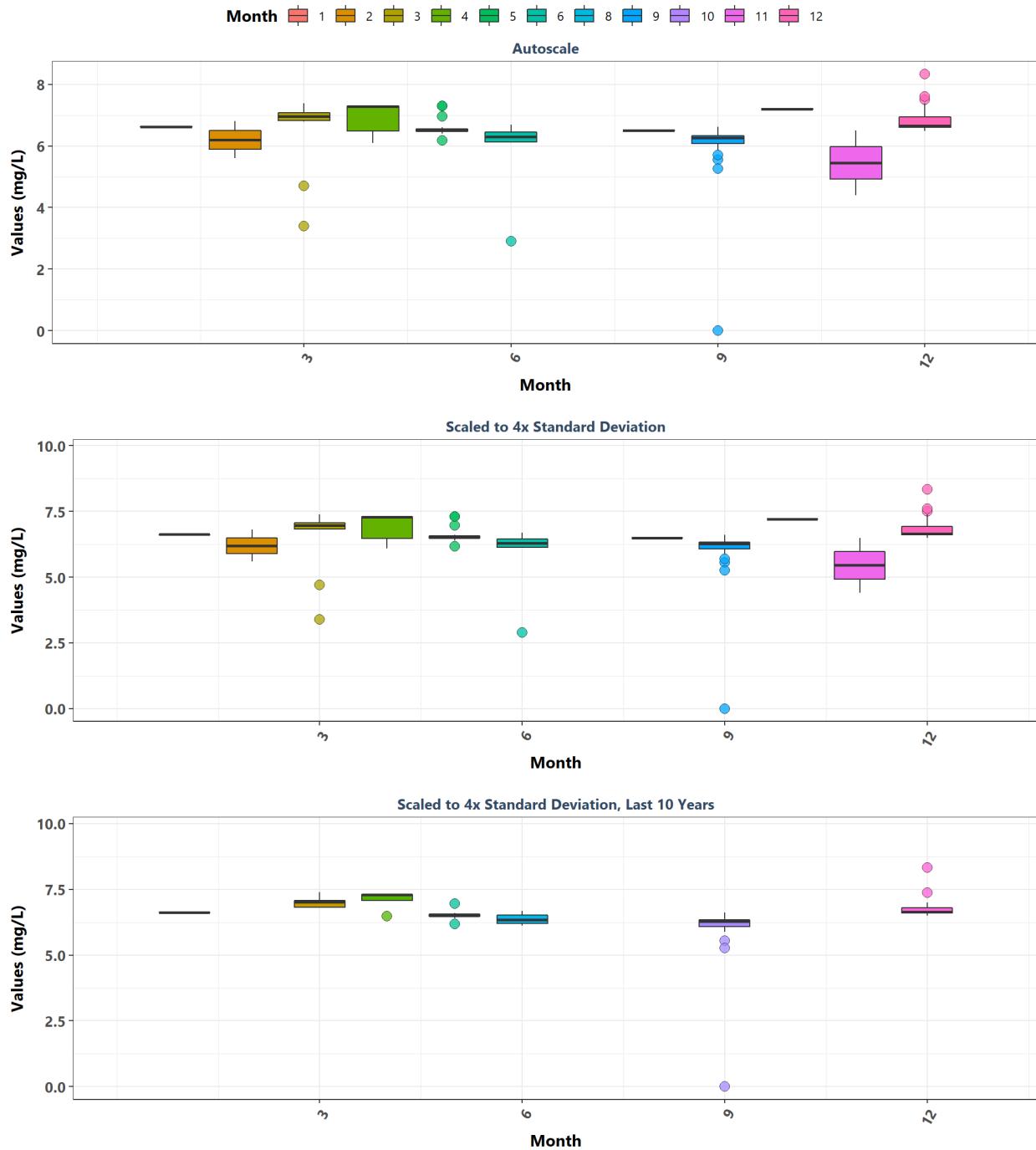
Southeast Florida Coral Reef Ecosystem Conservation Area
By Year



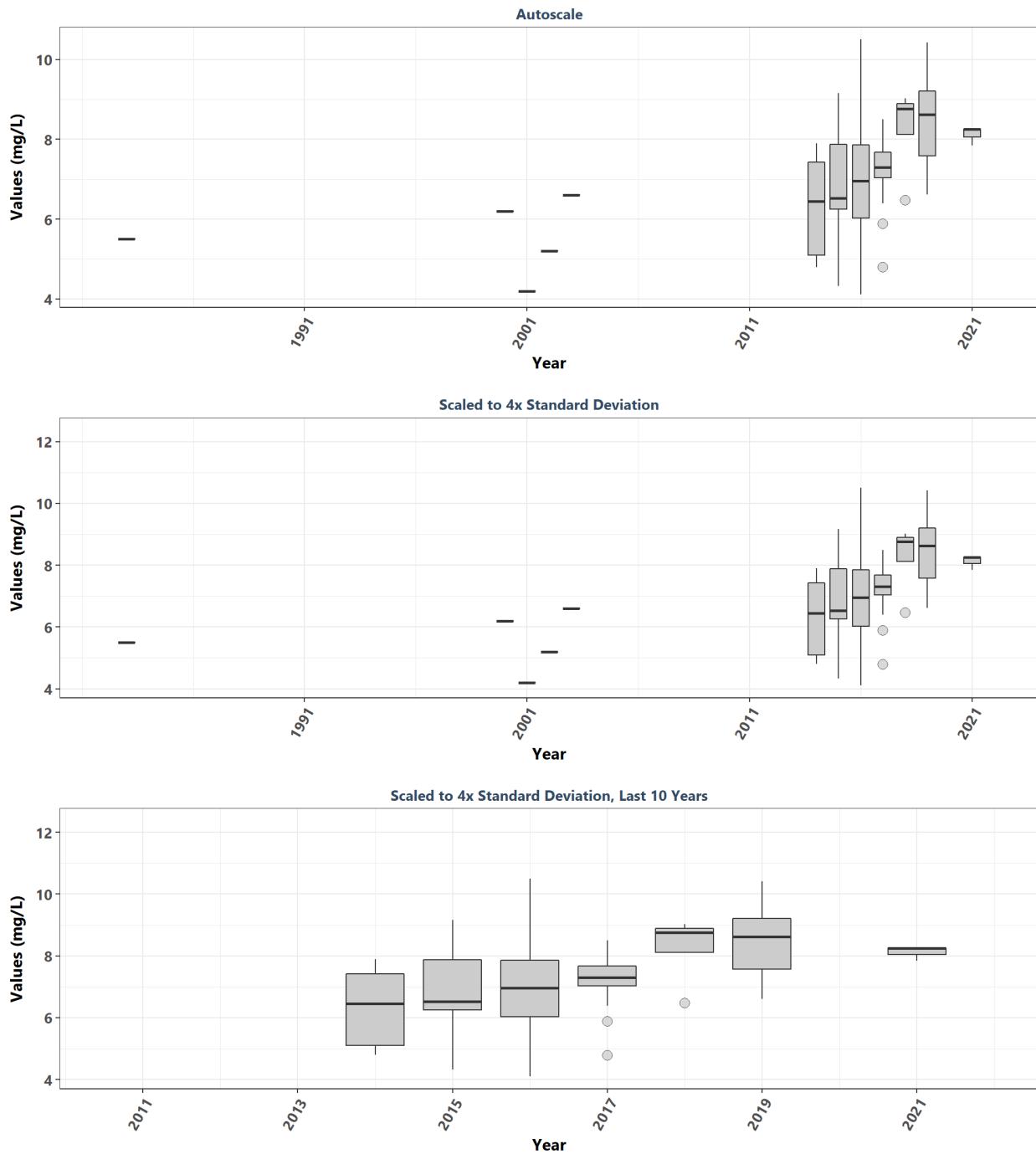
Southeast Florida Coral Reef Ecosystem Conservation Area
By Year & Month



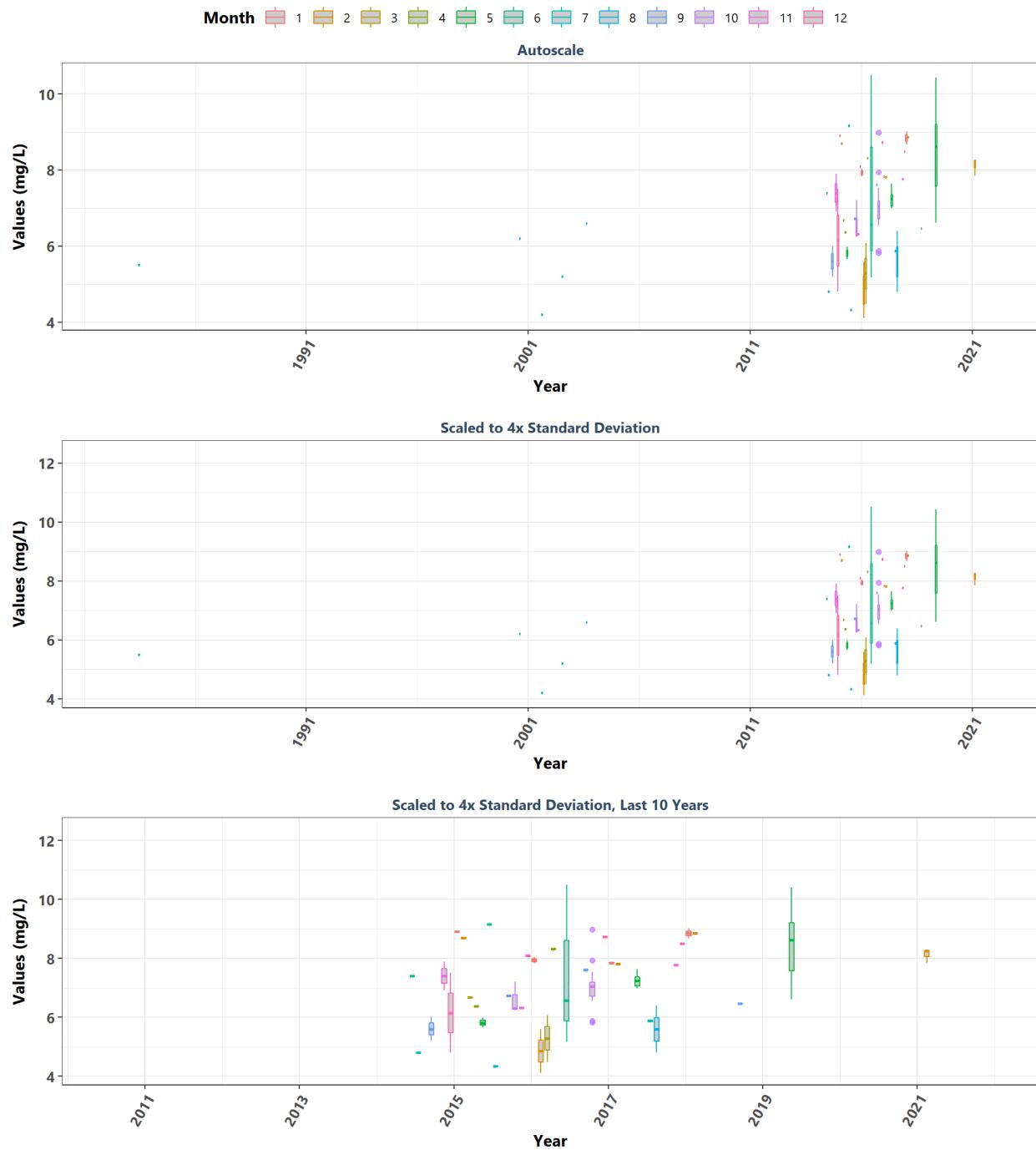
Southeast Florida Coral Reef Ecosystem Conservation Area
By Month



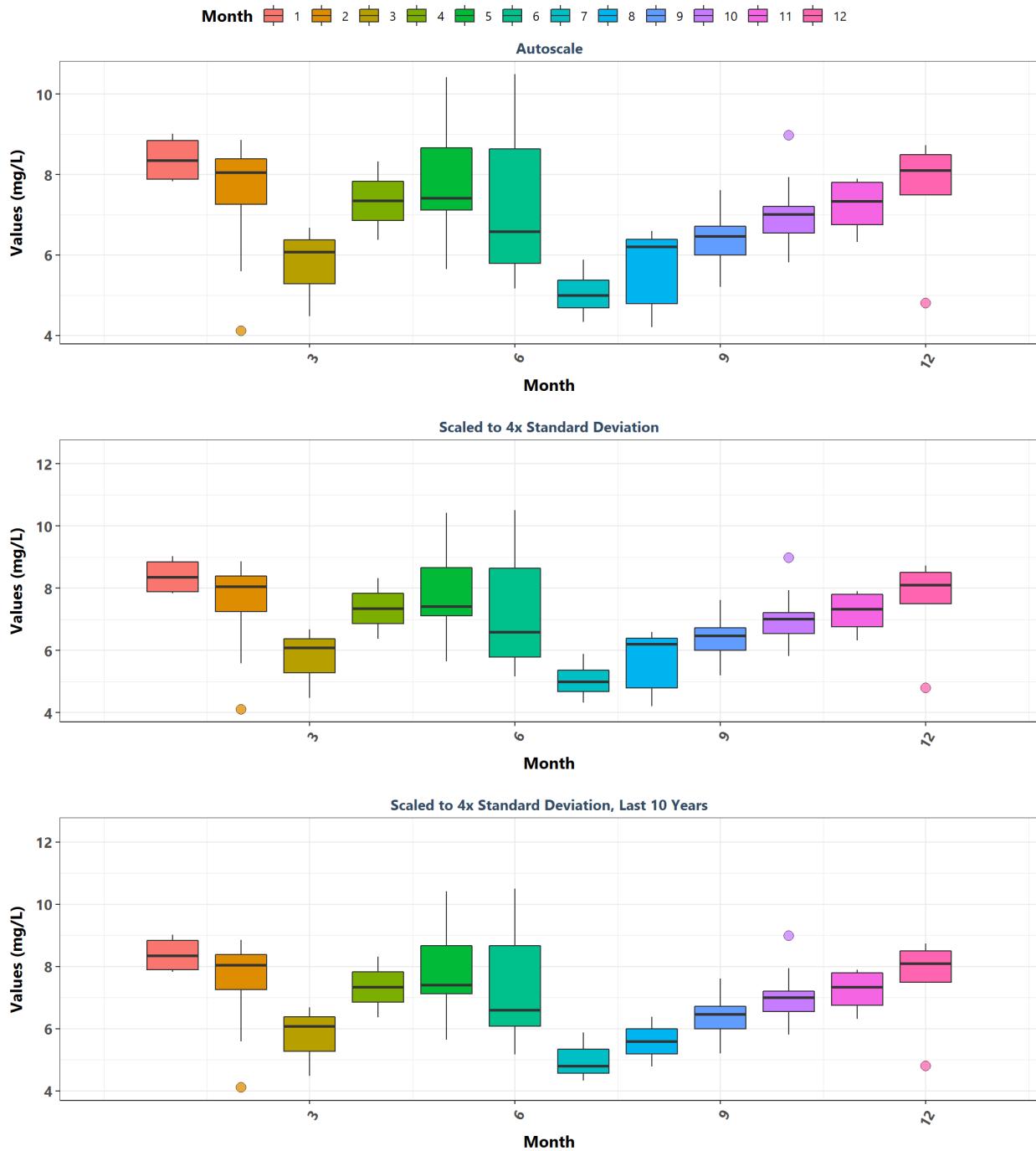
St. Andrews State Park Aquatic Preserve
By Year



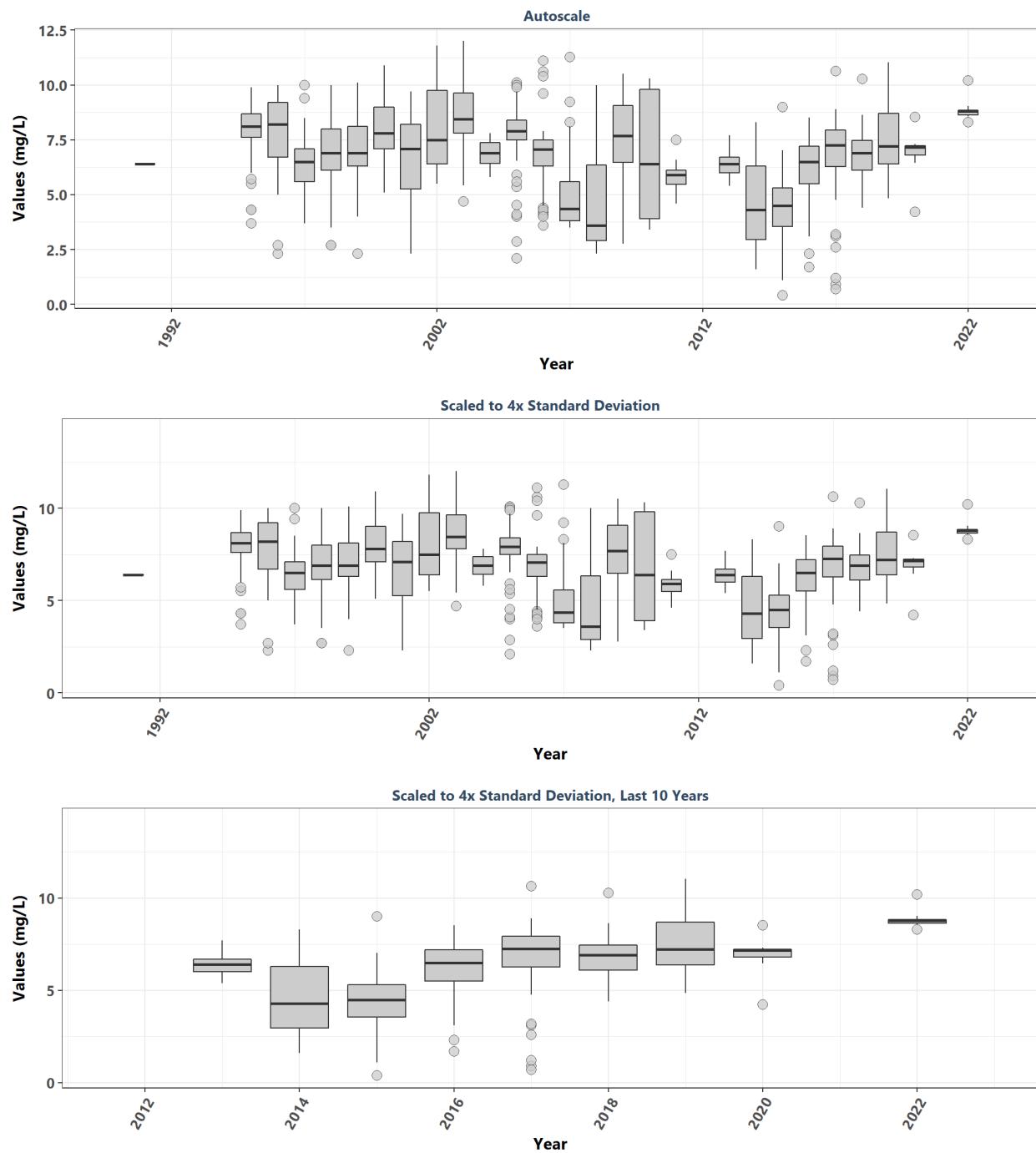
St. Andrews State Park Aquatic Preserve
By Year & Month



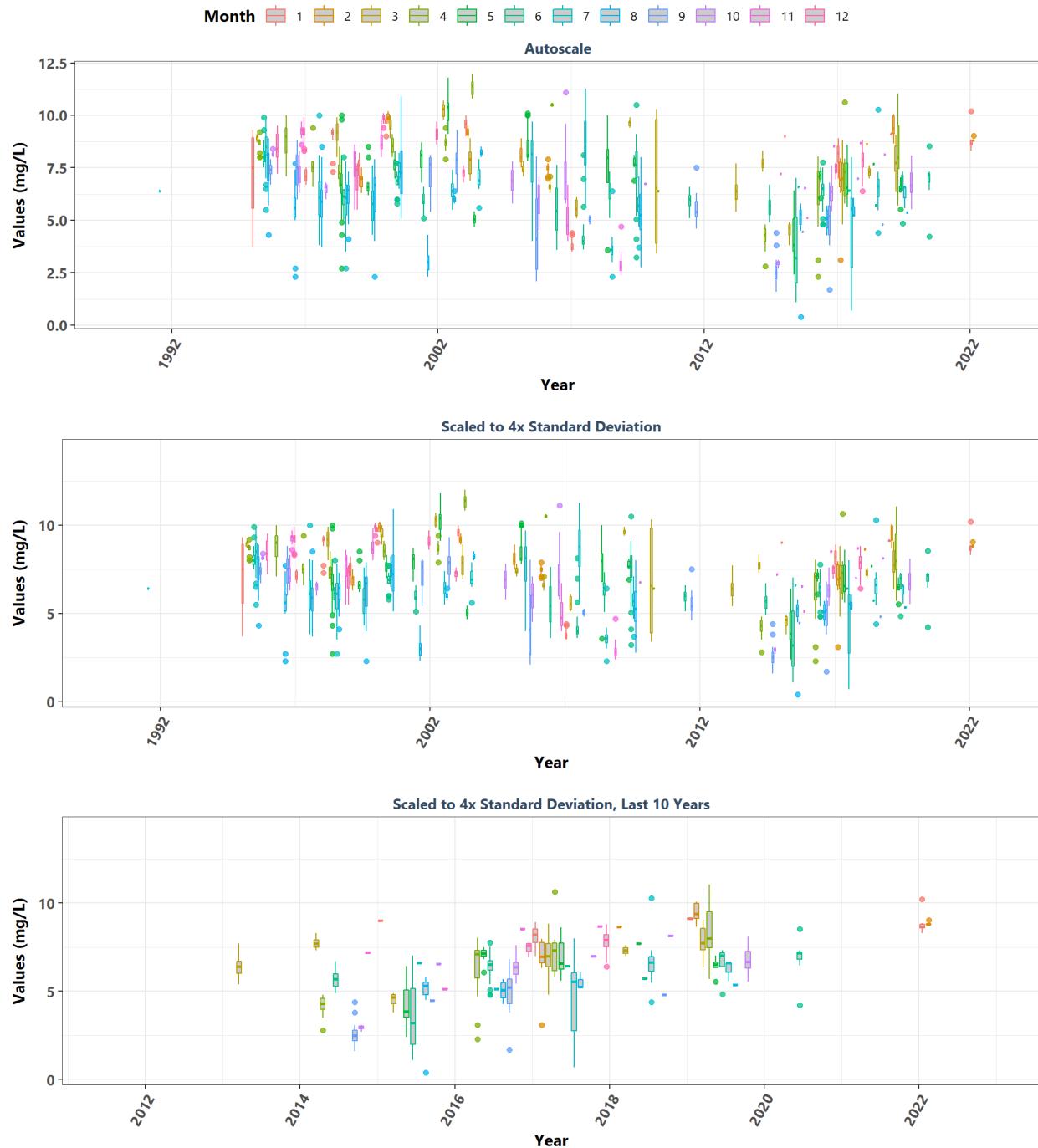
St. Andrews State Park Aquatic Preserve
By Month



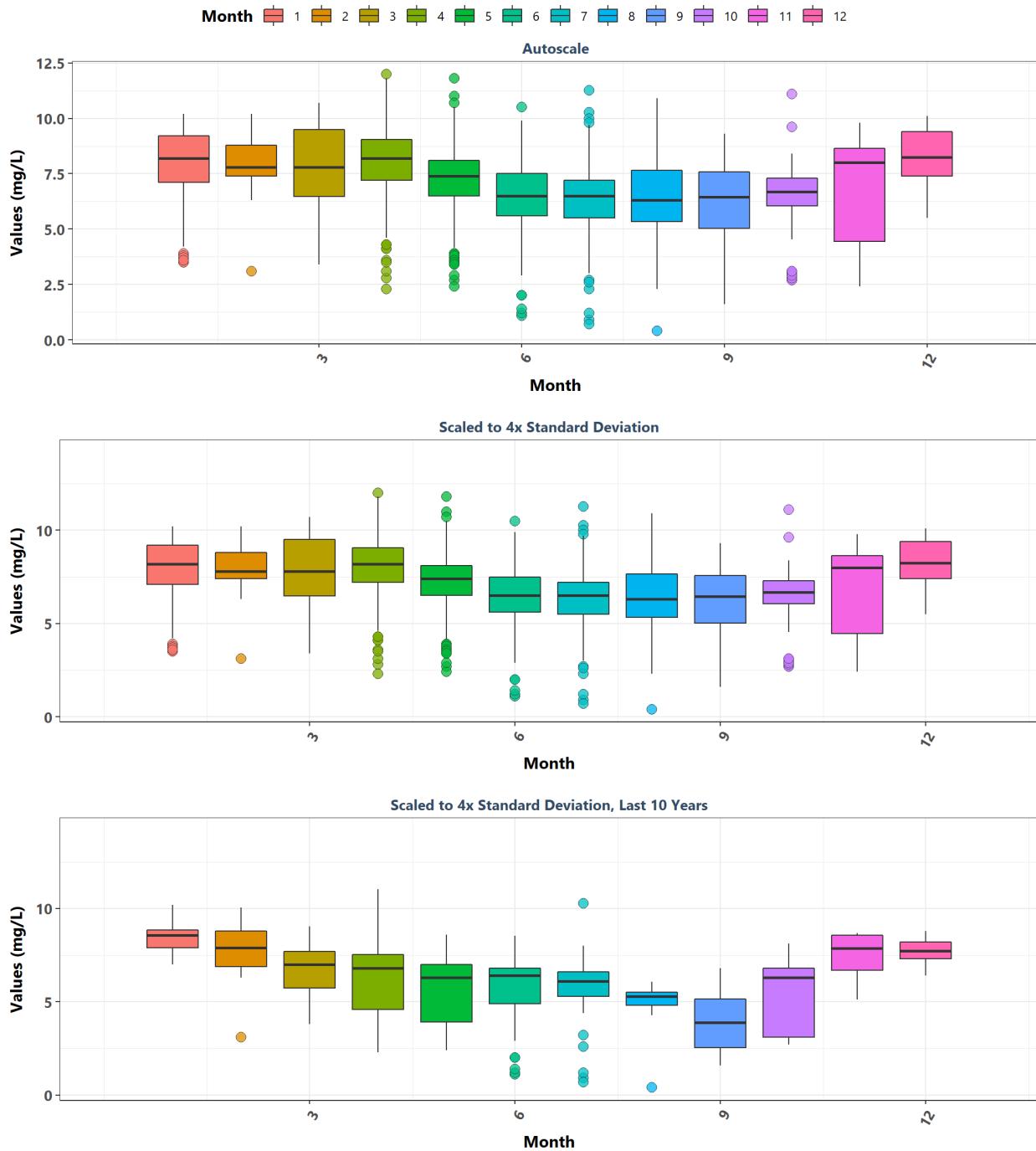
St. Joseph Bay Aquatic Preserve
By Year



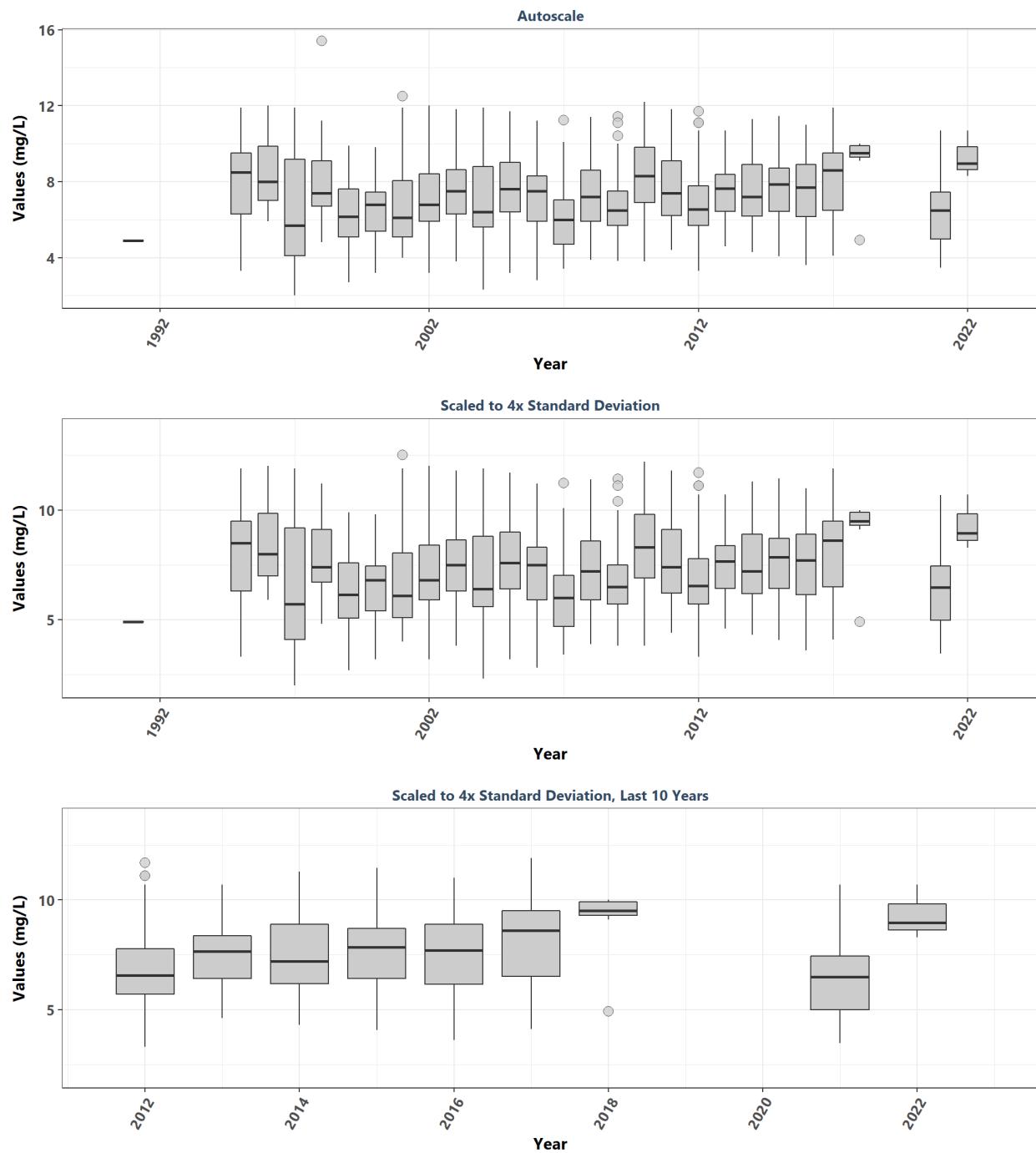
St. Joseph Bay Aquatic Preserve
By Year & Month



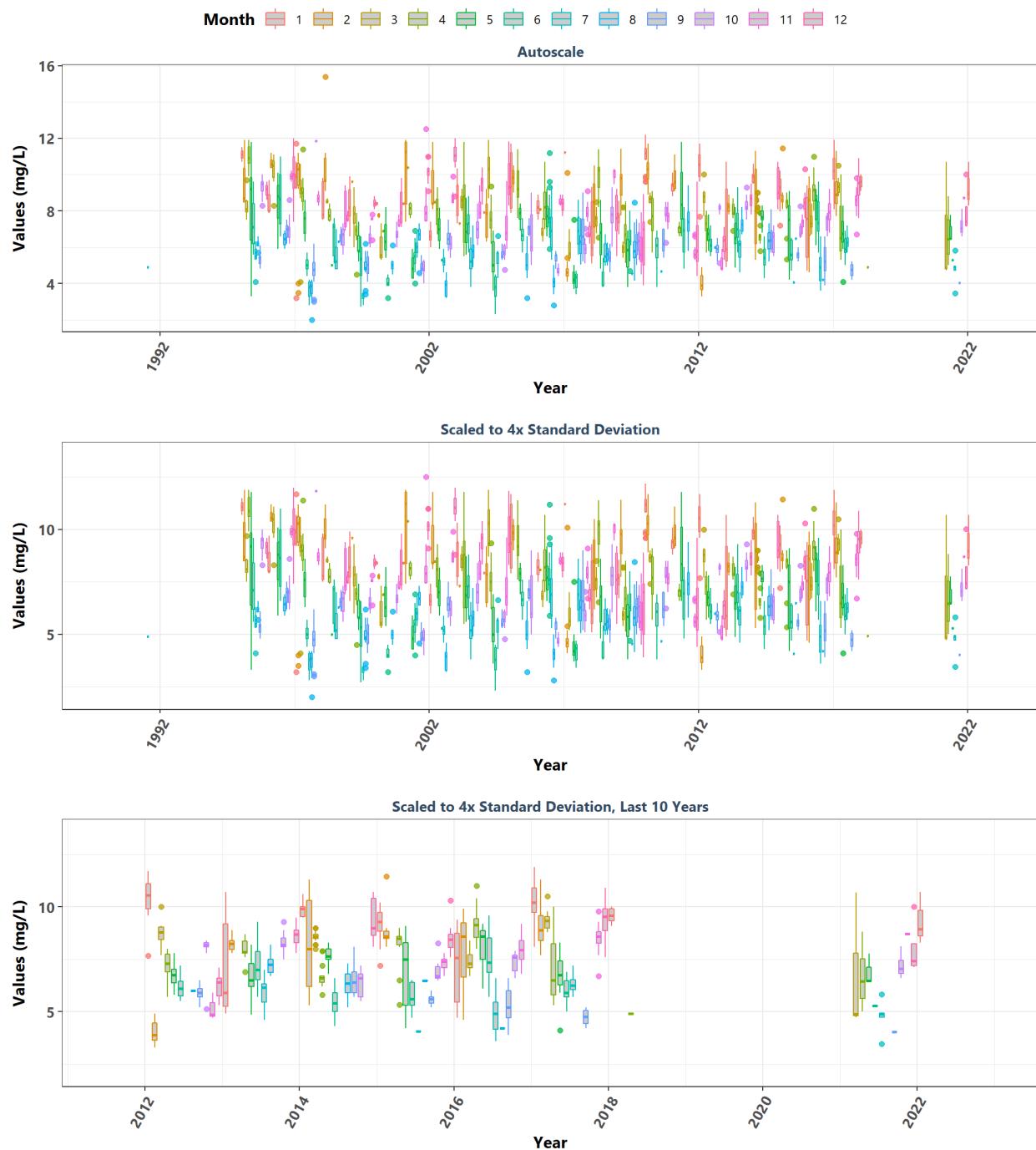
St. Joseph Bay Aquatic Preserve
By Month



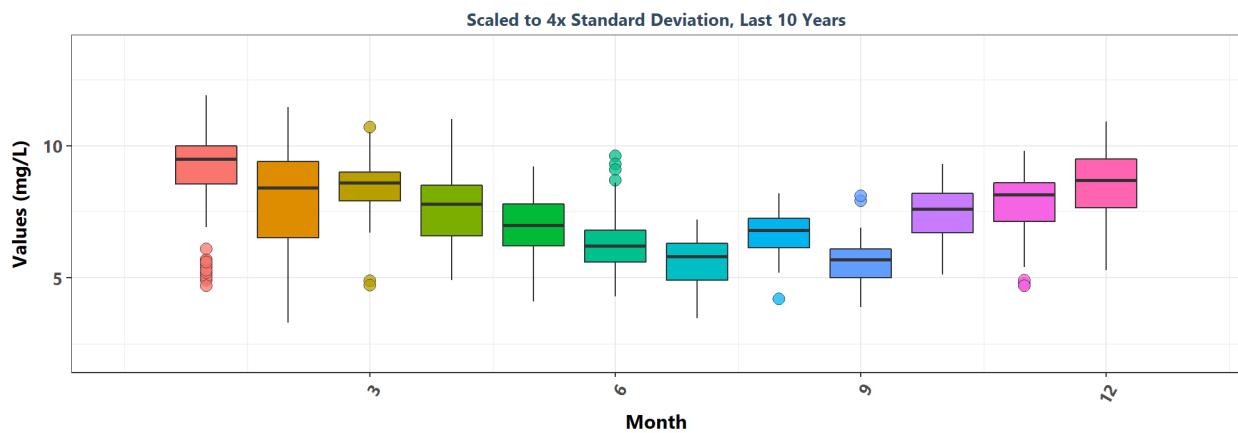
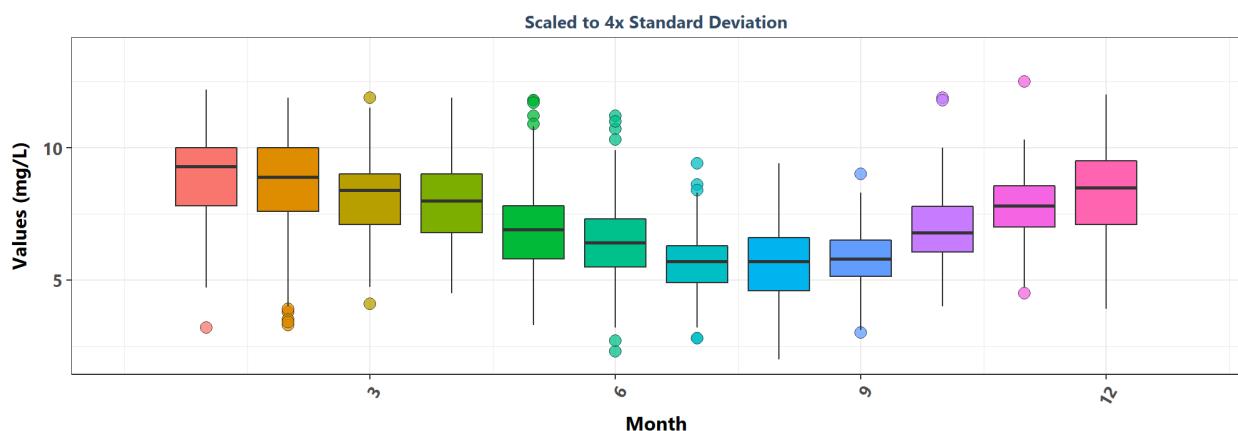
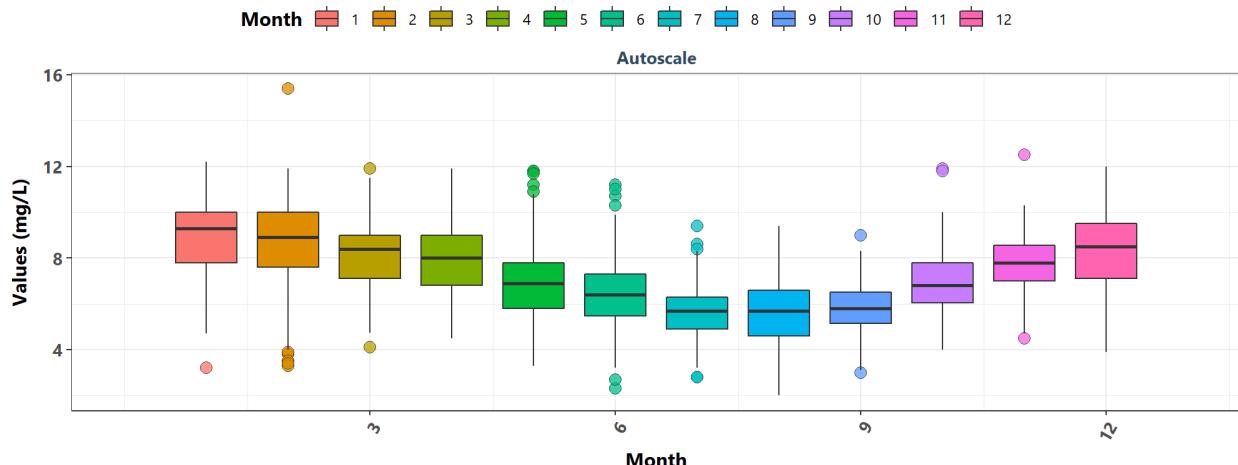
St. Martins Marsh Aquatic Preserve
By Year



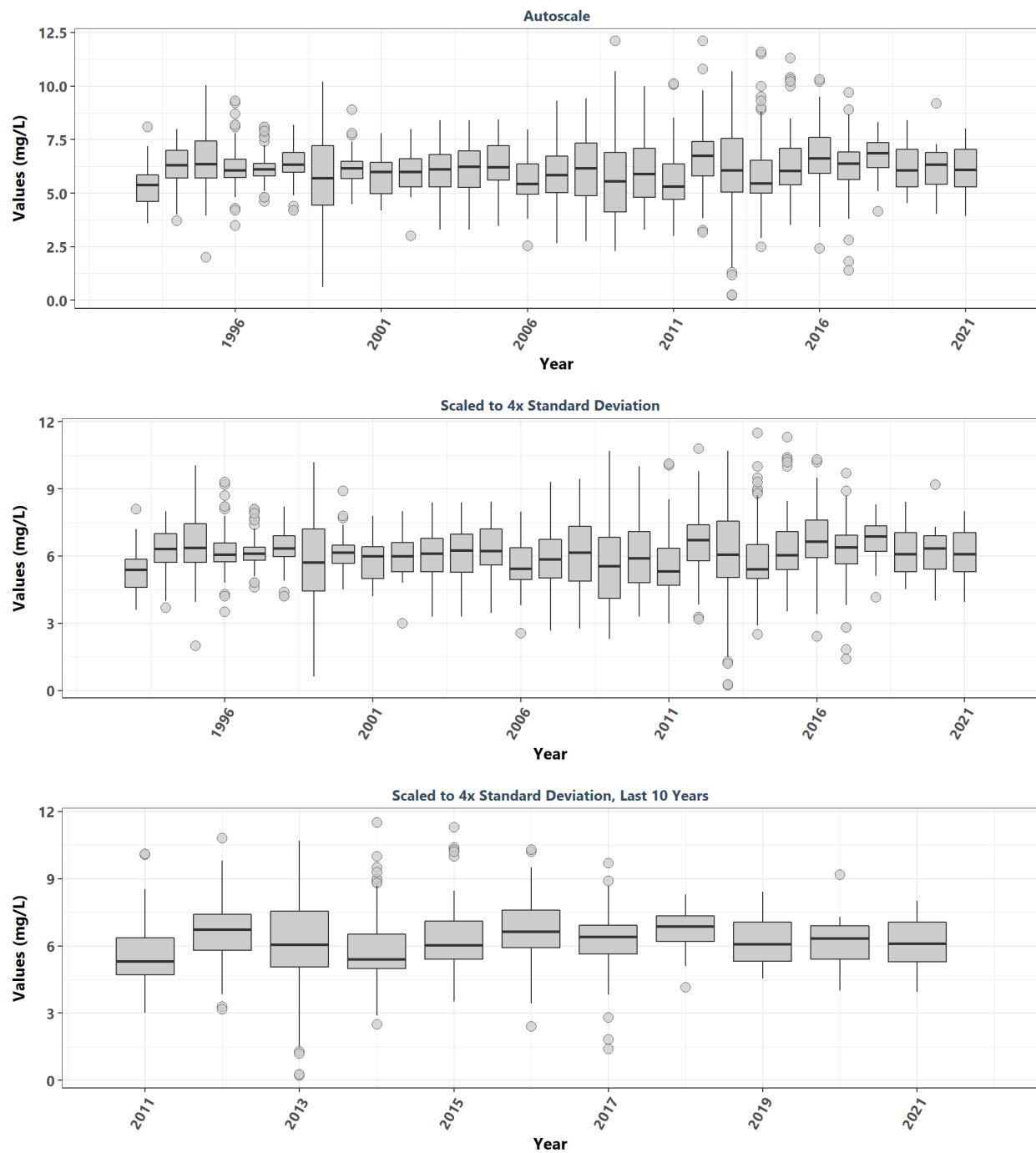
St. Martins Marsh Aquatic Preserve
By Year & Month



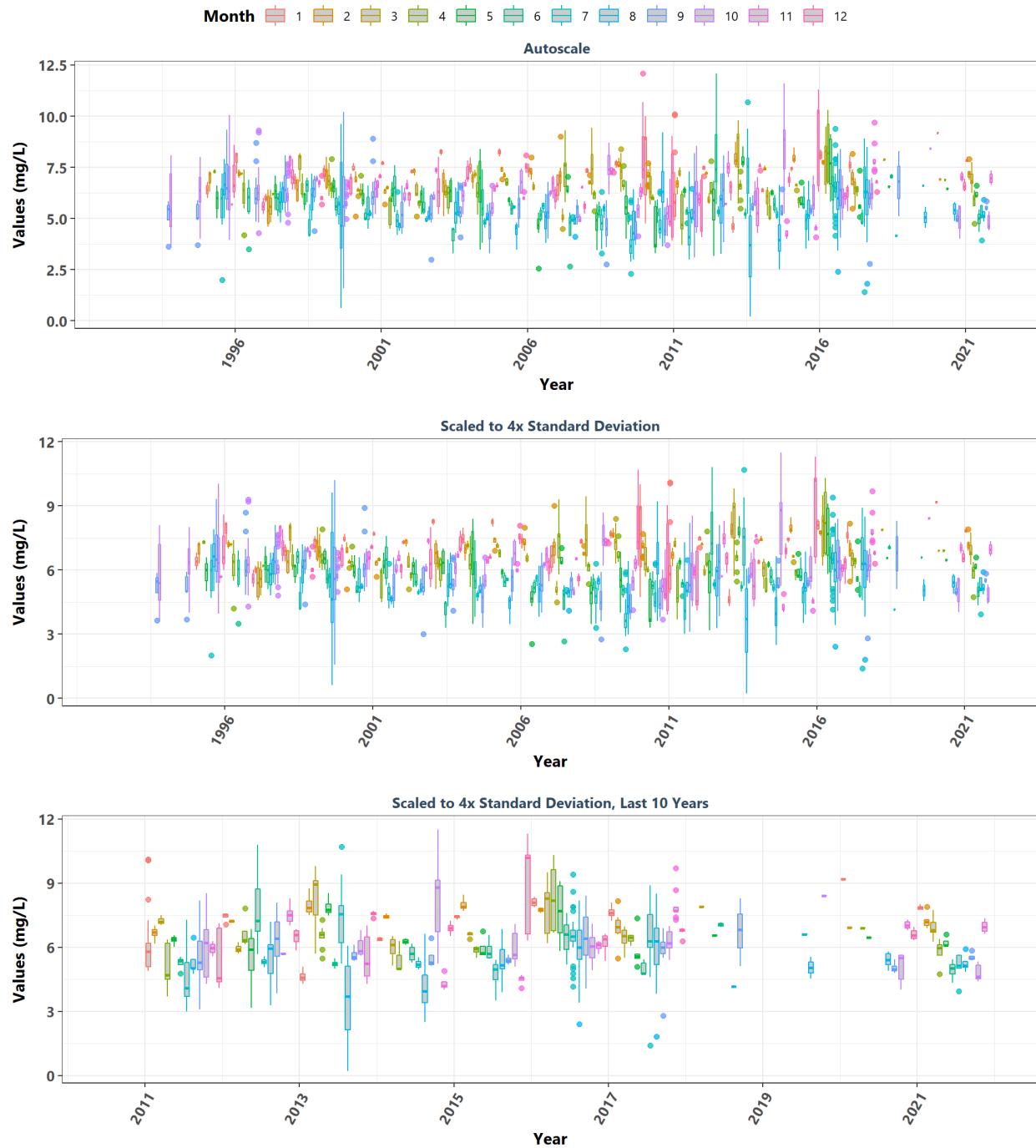
St. Martins Marsh Aquatic Preserve
By Month



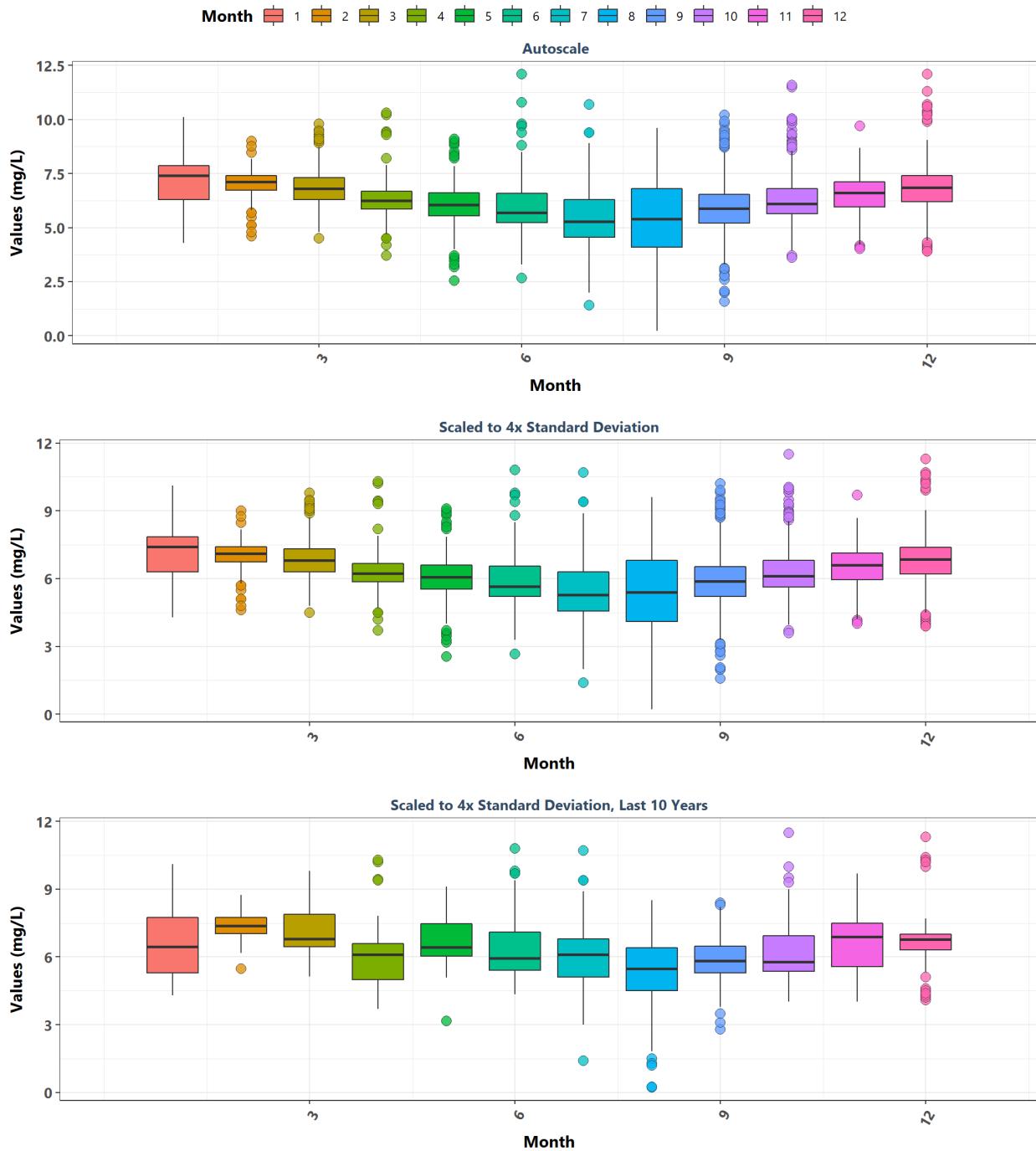
Terra Ceia Aquatic Preserve
By Year



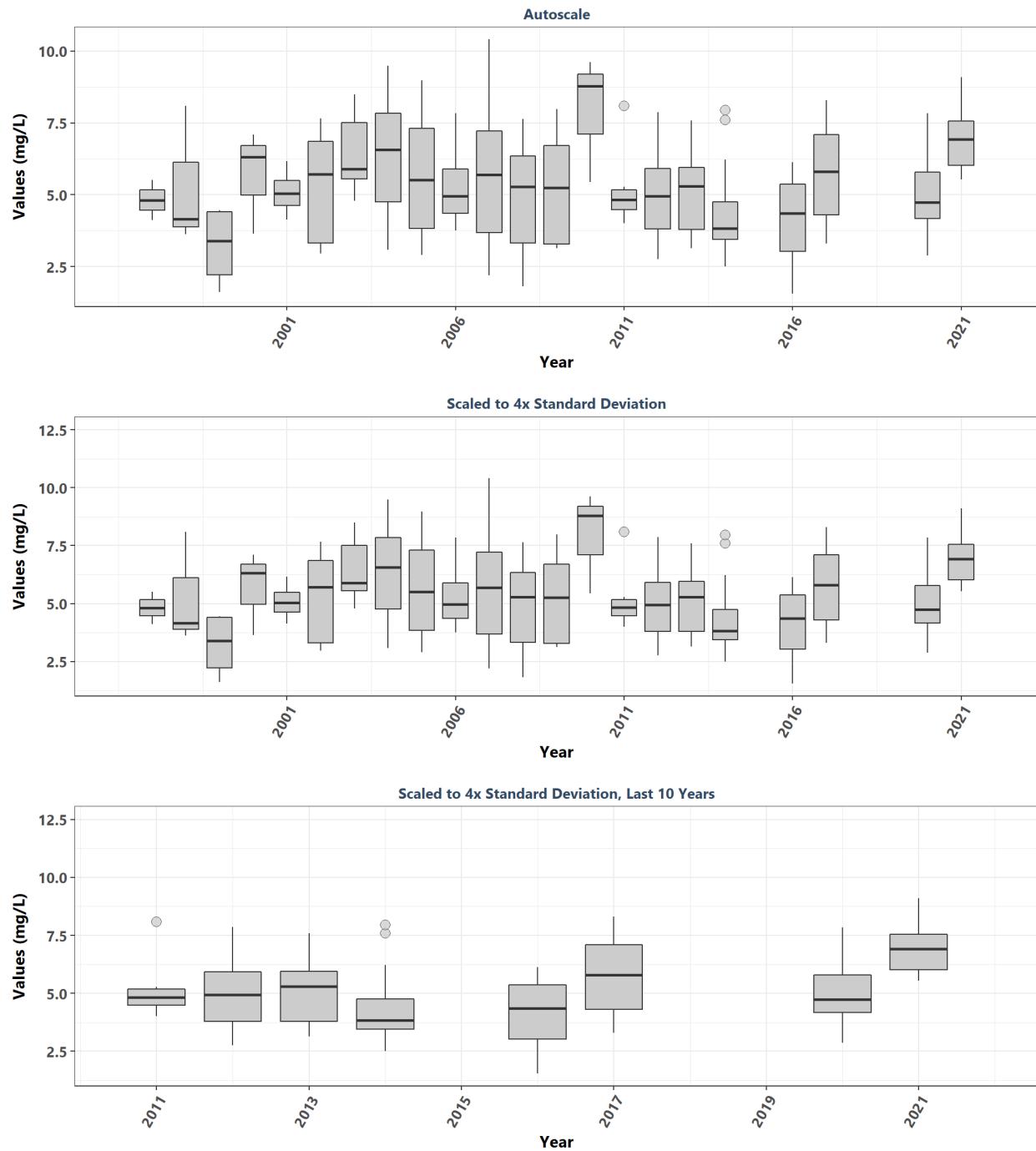
Terra Ceia Aquatic Preserve
By Year & Month



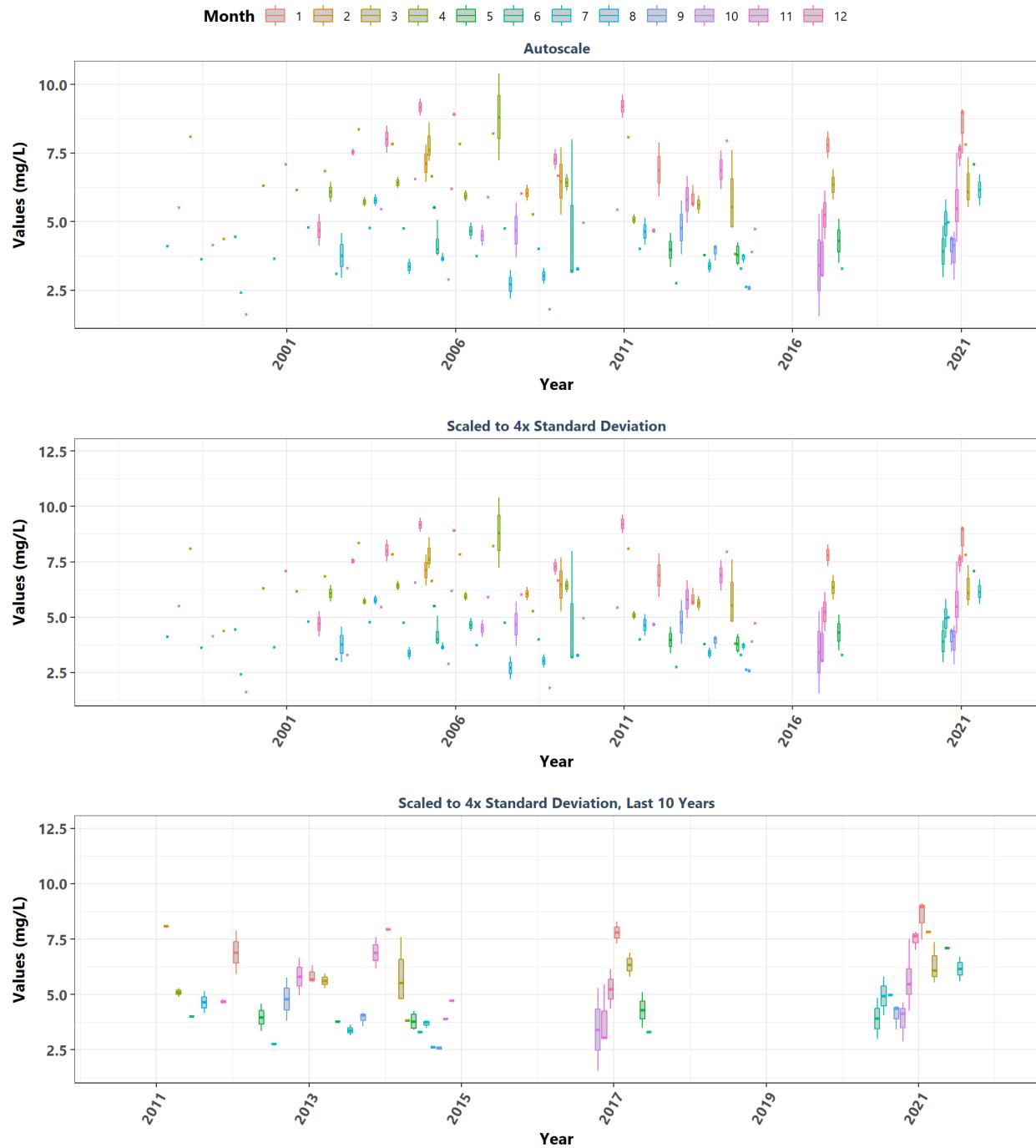
Terra Ceia Aquatic Preserve
By Month



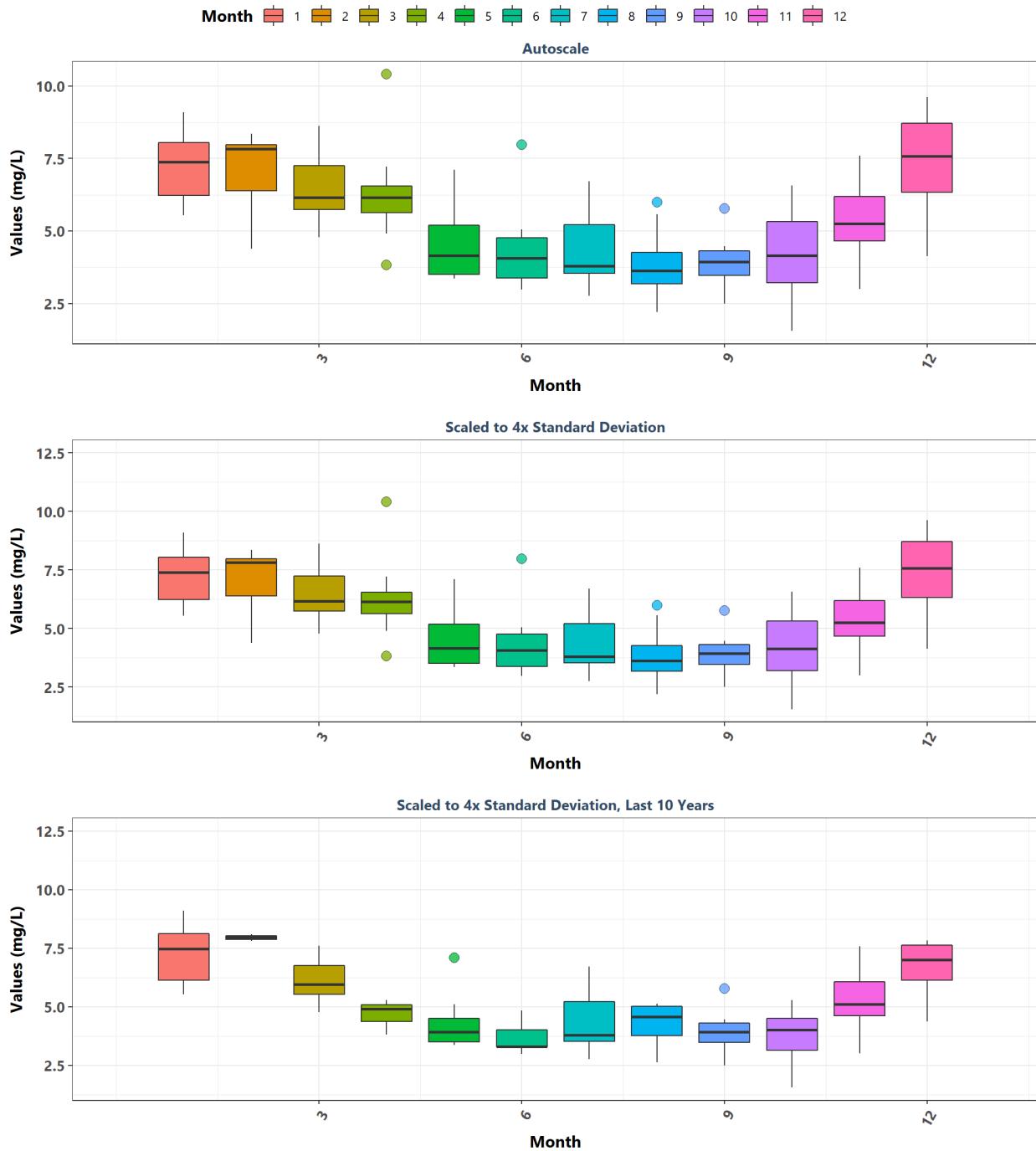
Tomoka Marsh Aquatic Preserve
By Year



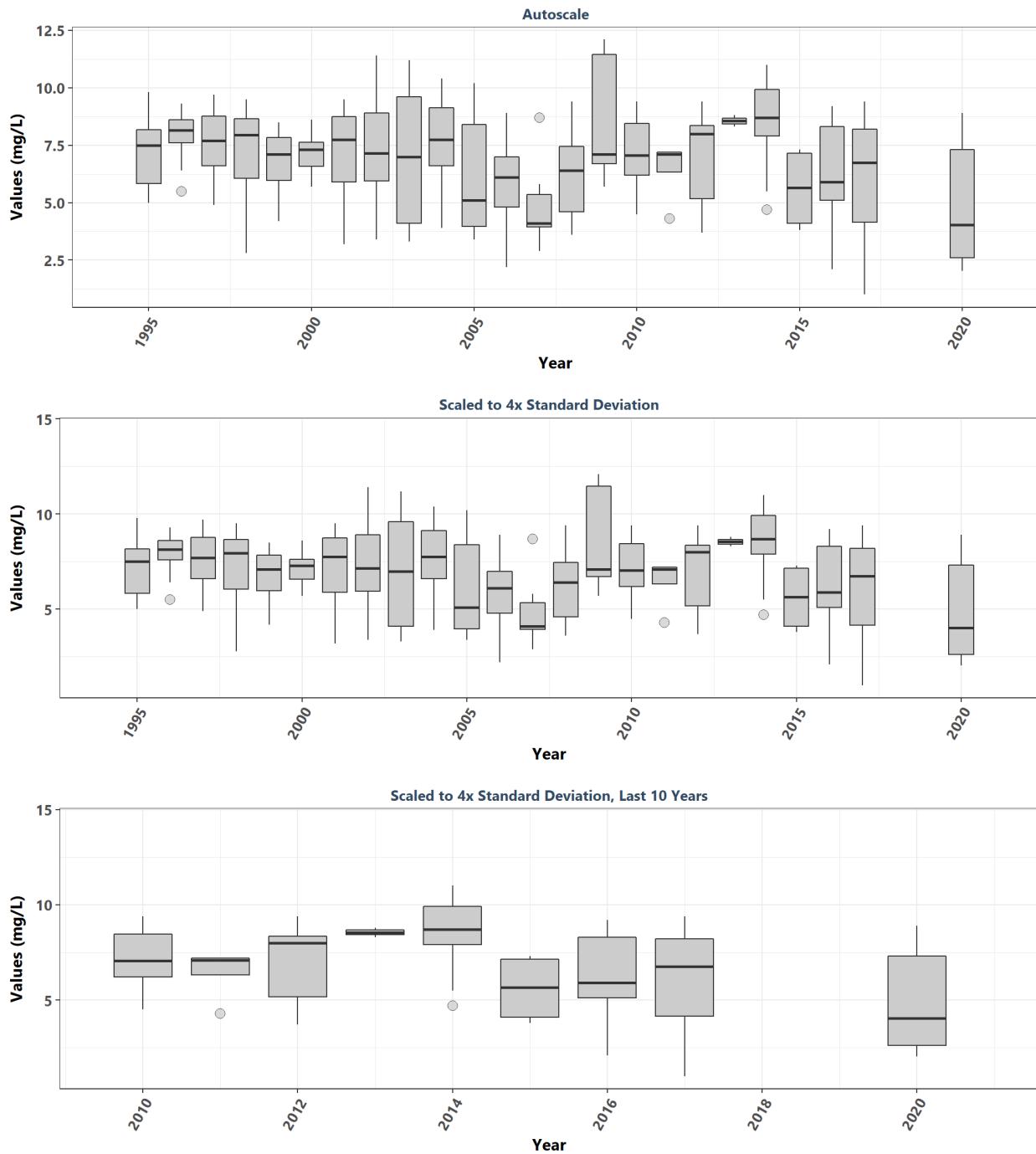
Tomoka Marsh Aquatic Preserve
By Year & Month



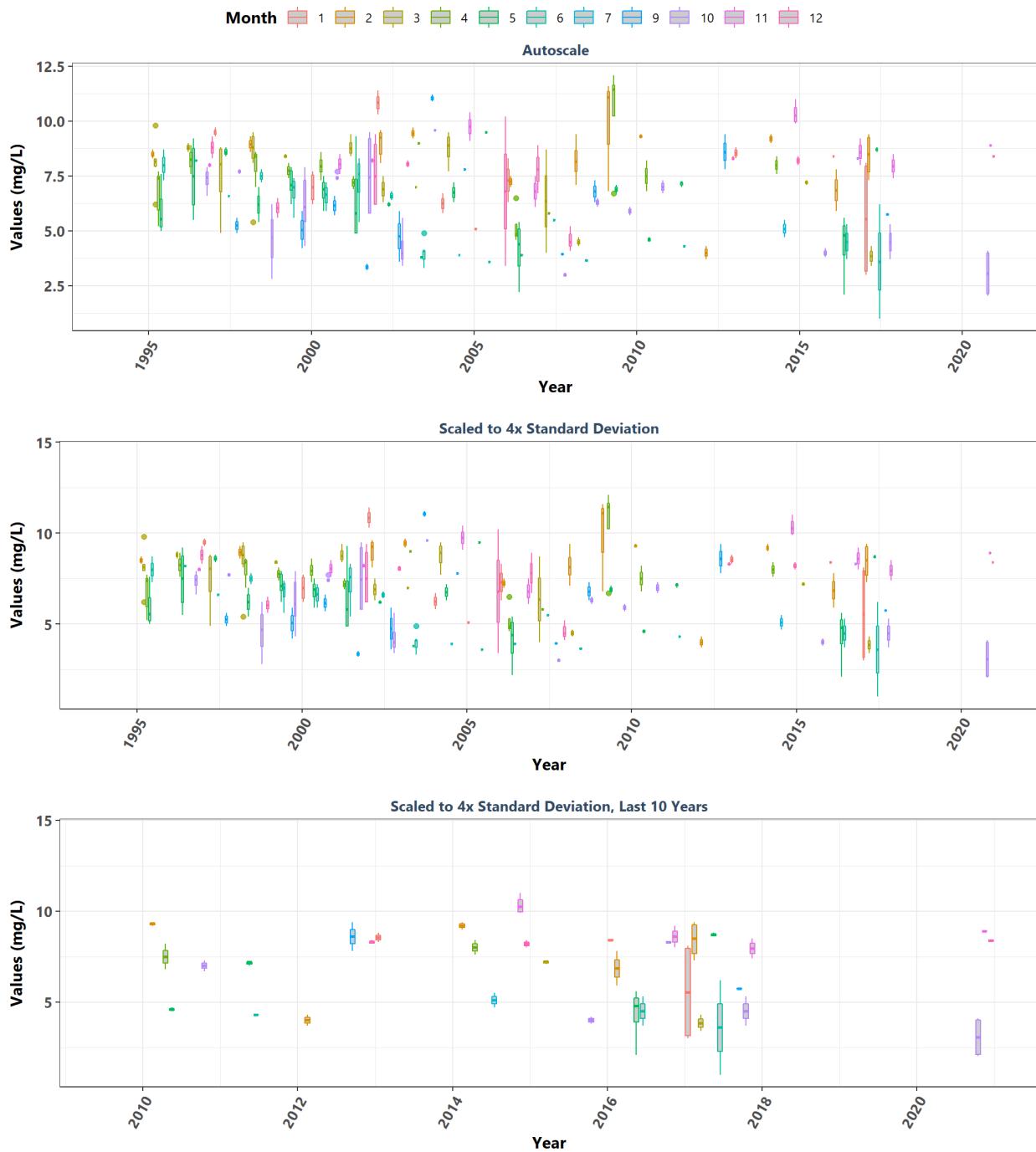
Tomoka Marsh Aquatic Preserve
By Month



Yellow River Marsh Aquatic Preserve
By Year



Yellow River Marsh Aquatic Preserve
By Year & Month



Yellow River Marsh Aquatic Preserve
By Month

