OGC-biomass

Environmental Comparisons

Kelly Murray Stoker, David Murray-Stoker

Contents

Load Data

```
## Read in sampling period environmental data
environmental.data <- read_csv("data/OGC_final_biomass_data.csv", show_col_types = FALSE) %>%
    select(UID, Year, Season, Period, CaCO, Carbon, Conductivity, DO, pH, Water_Temperature,
                 Air_Temperature, Precipitation, Mean_Discharge)

## Set variables as factors
environmental.data$UID              <- as_factor(environmental.data$UID)
environmental.data$Year             <- as_factor(environmental.data$Year)
environmental.data$Season           <- as_factor(environmental.data$Season)
environmental.data$Period           <- as_factor(environmental.data$Period)
```

USGS Discharge Data

We obtained average daily discharge (m^3 s^{-1}) and water chemistry metrics from the United States Geological Survey (USGS, gage 02202500) to calculate the average discharge over a two-week period preceding each sampling date. Discharge data were downloaded using the `waterData` package. Water and air temperature data were collected from the USGS water quality dataset, and precipitation data were gathered from the National Weather Service Forecast Office in Louisville, GA.

```r
## List of start dates
start.dates <- c("1981-12-02", "1982-01-09", "1982-02-15", "1982-03-09",
                 "1982-04-02", "1982-04-30", "1982-05-25", "1982-06-26",
                 "1982-07-23", "1982-08-19", "1982-09-15", "1982-10-15",
                 "1982-11-18", "1982-12-24", "1983-01-22", "1983-02-18",
                 "1983-03-25", "1983-04-23", "1983-05-20", "1983-06-17",
                 "1983-07-15", "1983-08-13", "1983-09-09", "1983-10-08",
                 "1983-11-04",
                 "2015-06-26", "2015-07-27", "2015-08-29", "2015-10-02",
                 "2015-11-06", "2015-12-03", "2016-01-21", "2016-02-24",
                 "2016-03-30", "2016-04-27", "2016-05-31", "2016-08-03",
                 "2016-09-05", "2016-10-05", "2016-11-02", "2016-11-30",
                 "2017-01-06", "2017-02-10", "2017-03-08", "2017-04-12",
                 "2017-05-03", "2017-05-29", "2017-07-05", "2017-08-08")

## List of end dates
end.dates <- c("1981-12-16", "1982-01-23", "1982-03-01", "1982-03-23",
               "1982-04-16", "1982-05-14", "1982-06-08", "1982-07-10",
               "1982-08-06", "1982-09-02", "1982-09-29", "1982-10-29",
               "1982-12-02", "1983-01-07", "1983-02-05", "1983-03-04",
               "1983-04-08", "1983-05-07", "1983-06-03", "1983-07-01",
               "1983-07-29", "1983-08-27", "1983-09-23", "1983-10-22",
               "1983-11-18",
               "2015-07-10", "2015-08-10", "2015-09-12", "2015-10-16",
               "2015-11-20", "2015-12-17", "2016-02-04", "2016-03-09",
               "2016-04-13", "2016-05-11", "2016-06-14", "2016-08-17",
               "2016-09-19", "2016-10-19", "2016-11-16", "2016-12-14",
               "2017-01-20", "2017-02-24", "2017-03-22", "2017-04-26",
               "2017-05-17", "2017-06-12", "2017-07-19", "2017-08-22")

## Bind start and end dates into a single dataframe
flow.dates <- as.data.frame(cbind(start.dates, end.dates))

## Add UID identifier to flow dates
flow.dates$UID <- environmental.data$UID
```

```r
## Empty dataframe for discharge data
discharge.data <- tibble(data.frame(matrix(0, nrow = 15, ncol = 49)))

## Append data for all dates
for(x in 1:49){
  require(waterData)
  bin.1 <- importDVs(staid = "02202500", code = "00060", stat = "00003",
                     sdate = flow.dates[x, 1],
                     edate = flow.dates[x, 2])
  bin.2 <- cleanUp(bin.1, task = "fix", replace = 0.001)
  bin.3 <- fillMiss(bin.1, block = 2, pmiss = 5, model = "trend",
                    smooth = FALSE, log = "y")
  bin.4 <- bin.3[, c(2, 3)]
  colnames(bin.4) <- c(flow.dates[x, 3])
  discharge.data[, x] <- bin.4[, 1]
}
```

```r
## Calculate two week mean & convert from ft3 to m3
mean.discharge <- sapply(discharge.data, mean)
metric.shift   <- (mean.discharge / 35.315)

## Create mean discharge dataframe
metric.shift            <- tibble(mean.discharge)
metric.shift$UID        <- environmental.data$UID
```

Sampling Period Environmental Comparisons

Environmental Variable ANOVAs

ANOVAs were conducted for discharge, precipitation, water temperature, and air temperature to test the effects of period, season, and the interaction with Type II sums-of-squares. ANOVA assumptions were inspected graphically using `check_model()`. Post-hoc Tukey's HSD tests were conducted using `HSD.test()` to examine for differences among groups for influential factors in the ANOVA. Effect sizes for the ANOVAs were calculated as η_P^2 using `eta_squared()`.

Discharge

```
discharge.anova <- lm(
    log(Mean_Discharge) ~ Period * Season, data = environmental.data
    )
```

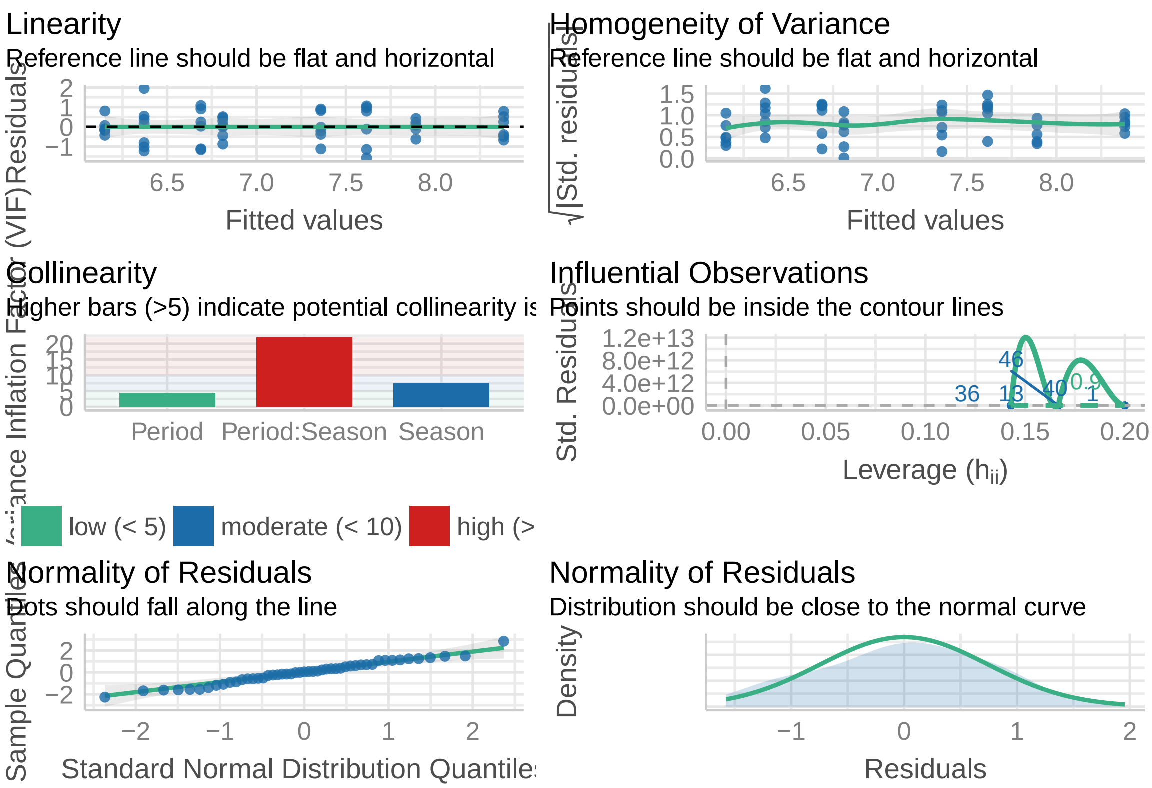

Figure 1: Diagnostic plots of the discharge ANOVA.

Table 1: ANOVA results for discharge by period, season, and the interaction.

	Sums-of-Squares	df	F	P-value
Period	0.412	1	0.637	0.429
Season	20.681	3	10.657	0.000
Period:Season	4.478	3	2.308	0.091
Residuals	26.522	41	NA	NA

Table 2: Tukey groups assigned to seasons differing in discharge.

	Discharge	Grouping
spring	7.871171	a
winter	7.740950	a
summer	6.591366	b
fall	6.420161	b

Table 3: Tukey groups assigned to season and period groups differing in discharge.

	Discharge	Grouping
spring:1980	8.382595	a
winter:2010	7.891476	ab
winter:1980	7.615511	abc
spring:2010	7.359747	abc
summer:1980	6.811530	bc
fall:2010	6.688773	bc
summer:2010	6.371203	c
fall:1980	6.151550	c

```r
## Calculating partial eta-squared for each factor in the discharge ANOVA
discharge.anova.eta.squared <- eta_squared(
    Anova(discharge.anova, type = "II"),
    partial = TRUE
    )
```

Table 4: Table of the effect sizes in the predator biomass ANOVA.

Term	Eta-squared	CI	CI_Low	CI_High
Period	0.015	0.95	0.000	1
Season	0.438	0.95	0.225	1
Period:Season	0.144	0.95	0.000	1

Precipitation

```
precipitation.anova <- lm(
    Precipitation ~ Period * Season, data = environmental.data
    )
```

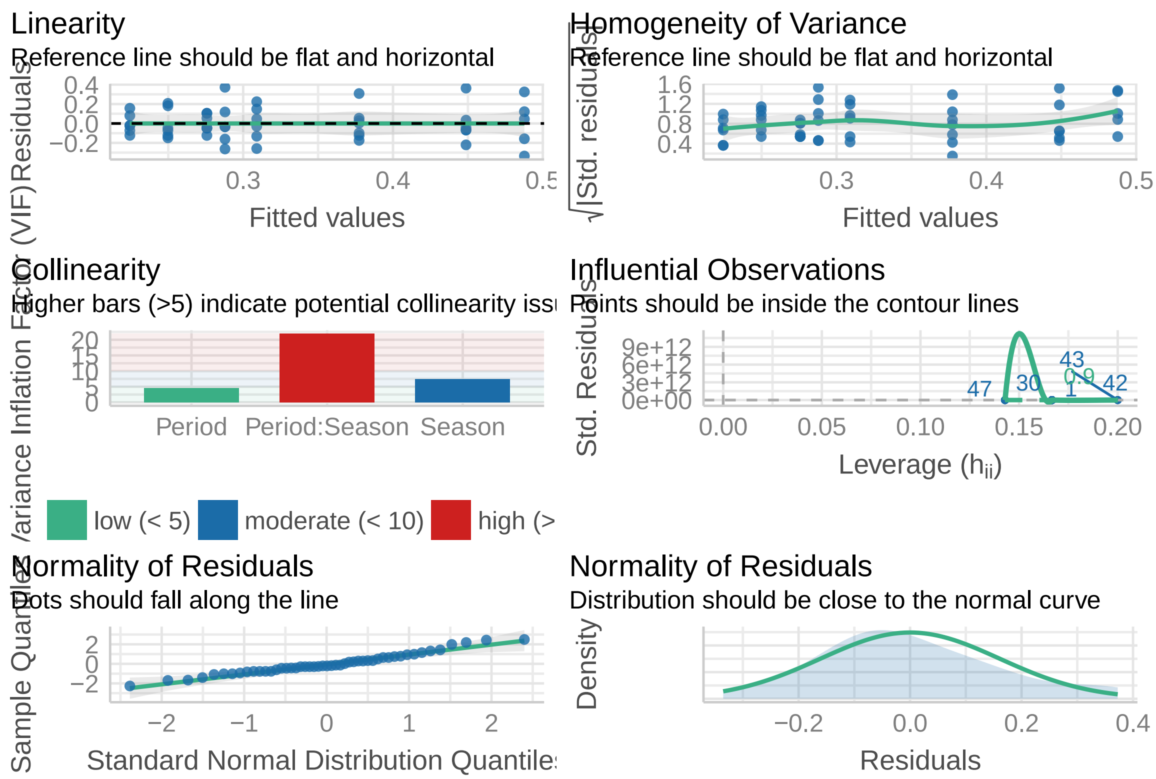

Figure 2: Diagnostic plots of the precipitation ANOVA.

Table 5: ANOVA results for precipitation by period, season, and the interaction.

	Sums-of-Squares	df	F	P-value
Period	0.008	1	0.282	0.599
Season	0.301	3	3.330	0.029
Period:Season	0.058	3	0.637	0.595
Residuals	1.236	41	NA	NA

Table 6: Tukey groups assigned to seasons differing in precipitation.

	Precipitation	Grouping
winter	0.4664364	a
summer	0.3265714	ab
fall	0.2688167	b
spring	0.2667000	b

```r
## Calculating partial eta-squared for each factor in the precipitation ANOVA
precipitation.anova.eta.squared <- eta_squared(
    Anova(precipitation.anova, type = "II"),
    partial = TRUE
    )
```

Table 7: Table of the effect sizes in the predator biomass ANOVA.

Term	Eta-squared	CI	CI_Low	CI_High
Period	0.007	0.95	0.000	1
Season	0.196	0.95	0.013	1
Period:Season	0.045	0.95	0.000	1

Water Temperature

```
water.temperature.anova <- lm(
    Water_Temperature ~ Period * Season, data = environmental.data
    )
```

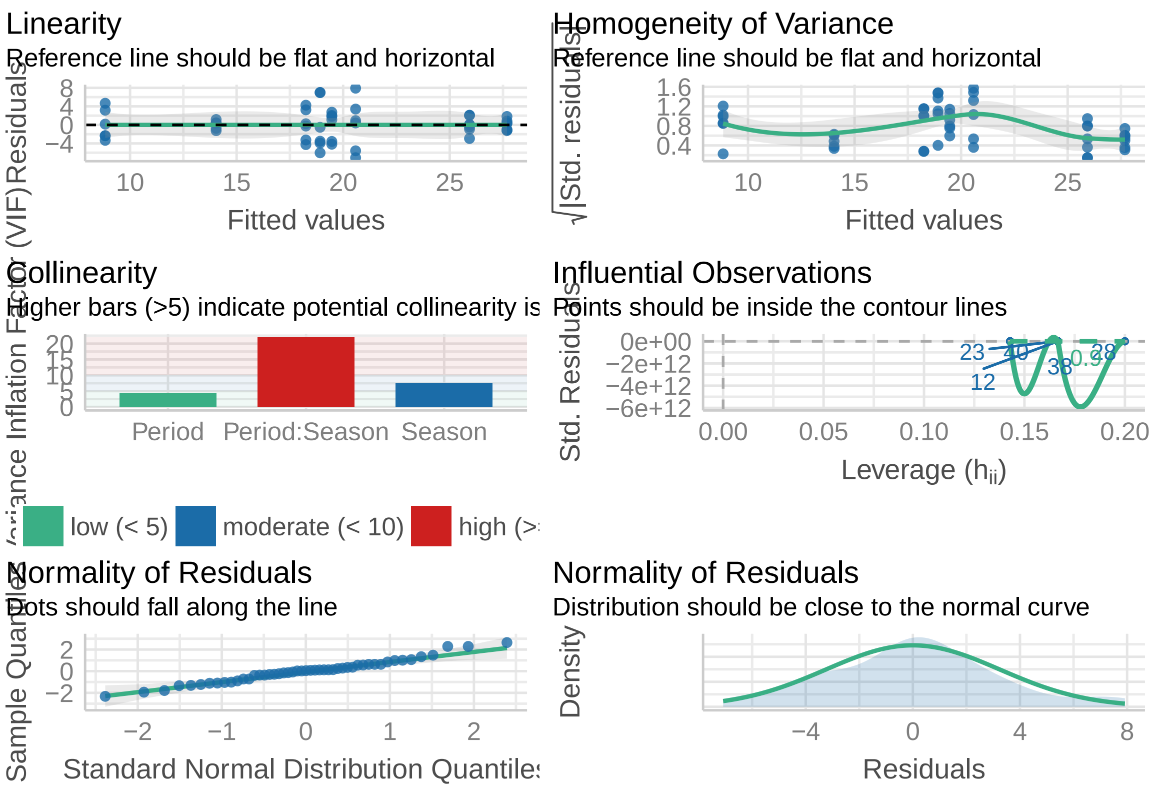

Figure 3: Diagnostic plots of the water temperature ANOVA.

Table 8: ANOVA results for water.temperature by period, season, and the interaction.

	Sums-of-Squares	df	F	P-value
Period	29.524	1	2.392	0.130
Season	1495.705	3	40.402	0.000
Period:Season	67.991	3	1.837	0.156
Residuals	505.953	41	NA	NA

Table 9: Tukey groups assigned to seasons differing in water temperature.

	Water Temperature	Grouping
summer	26.80714	a
fall	19.75000	b
spring	18.85833	b
winter	11.20000	c

```r
## Calculating partial eta-squared for each factor in the water temperature ANOVA
water.temperature.anova.eta.squared <- eta_squared(
    Anova(water.temperature.anova, type = "II"),
    partial = TRUE
    )
```

Table 10: Table of the effect sizes in the predator biomass ANOVA.

Term	Eta-squared	CI	CI_Low	CI_High
Period	0.055	0.95	0.000	1
Season	0.747	0.95	0.625	1
Period:Season	0.118	0.95	0.000	1

Air Temperature

```
air.temperature.anova <- lm(
    Air_Temperature ~ Period * Season, data = environmental.data
    )
```

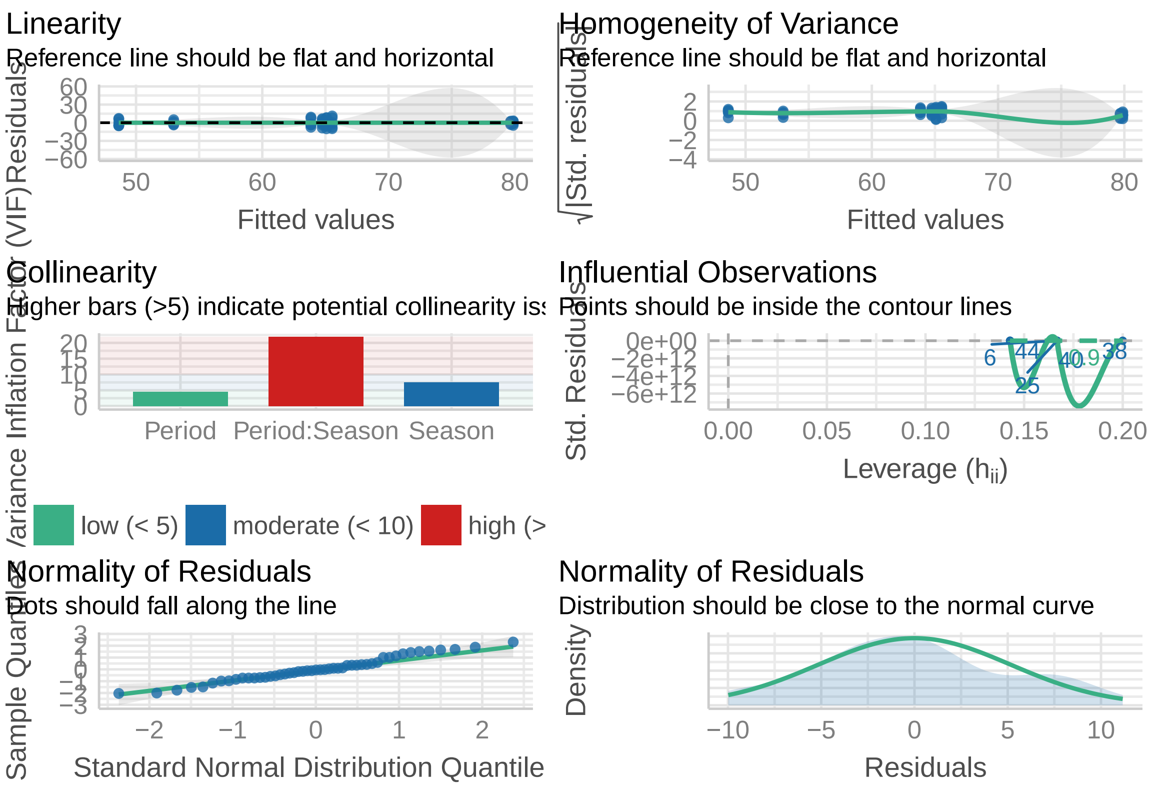

Figure 4: Diagnostic plots of the air temperature ANOVA.

Table 11: ANOVA results for air.temperature by period, season, and the interaction.

	Sums-of-Squares	df	F	P-value
Period	18.907	1	0.610	0.439
Season	5276.960	3	56.783	0.000
Period:Season	35.798	3	0.385	0.764
Residuals	1270.062	41	NA	NA

Table 12: Tukey groups assigned to seasons differing in air temperature.

	Air Temperature	Grouping
summer	79.77143	a
fall	65.30833	b
spring	64.30000	b
winter	50.60909	c

```r
## Calculating partial eta-squared for each factor in the air temperature ANOVA
air.temperature.anova.eta.squared <- eta_squared(
    Anova(air.temperature.anova, type = "II"),
    partial = TRUE
    )
```

Table 13: Table of the effect sizes in the predator biomass ANOVA.

Term	Eta-squared	CI	CI_Low	CI_High
Period	0.015	0.95	0.00	1
Season	0.806	0.95	0.71	1
Period:Season	0.027	0.95	0.00	1

Long-Term Environmental Comparisons

Data Management

We obtained historical USGS discharge data from December 1969 to November 2018 to determine average daily discharge for the winter-spring season of each year. Water and air temperature data collected from 1974 until 2018 were also obtained from the USGS water quality dataset. Precipitation data from 1970 until 2018 were obtained from the National Weather Service Forecast Office in Louisville, GA. We then filtered the long-term environmental data to only include the winter-spring season group (winter months = December, January, and February; spring months = March, April, and May), which are important for the flood pulse into the Ogeechee River. Mean values were then aggregated by year to generate a mean winter-spring value per year for use in time series analyses. Trends in the the time series were analyzed with Mann-Kendall tests using `MannKendall()`.

```
## Read in long-term environmental data
long.term.environmental.data <- read_csv(
    "data/OGC_long_term_environmental_data.csv", show_col_types = FALSE)

## Subset data by season groups
winter.spring.data <- long.term.environmental.data %>%
    filter(Season_Group == "WinterSpring")
```

```
## Aggregate mean values by year for the winter-spring data

## Winter-spring discharge
winter.spring.discharge <- aggregate(
    Mean_Discharge ~ Year,
    data = winter.spring.data,
    FUN = mean
    )

## Winter-spring precipitation
winter.spring.precipitation <- aggregate(
    Precipitation ~ Year,
    data = winter.spring.data,
    FUN = mean
    ) %>%
    na.omit()

## Winter-spring water temperature
winter.spring.water.temperature <- aggregate(
    Water_Temperature ~ Year,
    data = winter.spring.data,
    FUN = mean
    ) %>%
    na.omit()

## Winter-spring air temperature
winter.spring.air.temperature <- aggregate(
    Air_Temperature ~ Year,
    data = winter.spring.data,
    FUN = mean
    ) %>%
```

```
    na.omit()
```

Mann-Kendall Tests on Winter-Spring Trends

We assessed temporal trends in discharge, precipitation, water temperature, and air temperature using Mann-Kendall tests for the winter-spring season group (i.e., flood-prone seasons). We calculated monthly averages for each variable, and then assessed a shift in the time series using `MannKendall()`.

```
MannKendall(winter.spring.discharge$Mean_Discharge)
# tau = -0.248, P = 0.012
```

```
MannKendall(winter.spring.precipitation$Precipitation)
# tau = -0.087, P = 0.384
```

```
MannKendall(winter.spring.air.temperature$Air_Temperature)
# tau = -0.11, P = 0.270
```

```
MannKendall(winter.spring.water.temperature$Water_Temperature)
# tau = 0.442, P < 0.001
```

R Session Information

Table 14: R session information for transparency and reproducing results.

Setting	Value
version	R version 4.1.2 (2021-11-01)
os	macOS Big Sur 10.16
system	x86_64, darwin17.0
ui	X11
language	(EN)
collate	en_CA.UTF-8
ctype	en_CA.UTF-8
tz	America/Toronto
date	2022-01-16
pandoc	2.14.0.3 @ /Applications/RStudio.app/Contents/MacOS/pandoc/ (via rmarkdown)

Table 15: Packages for data management and analysis.

Package	Loaded Version	Date
agricolae	1.3-5	2021-06-06
bayestestR	0.11.5	2021-10-30
car	3.0-12	2021-11-06
carData	3.0-5	2022-01-06
correlation	0.7.1	2021-10-06
datawizard	0.2.2	2022-01-04
dplyr	1.0.7	2021-06-18
easystats	0.4.3	2021-11-07
effectsize	0.5	2021-10-04
forcats	0.5.1	2021-01-27
ggplot2	3.3.5	2021-06-25
insight	0.15.0	2022-01-07
kableExtra	1.3.4	2021-02-20
Kendall	2.2	2011-05-18
knitr	1.37	2021-12-16
modelbased	0.7.0.1	2021-11-17
parameters	0.15.0	2021-10-18
performance	0.8.0	2021-10-01
purrr	0.3.4	2020-04-17
readr	2.1.1	2021-11-30
report	0.4.0	2021-09-30
see	0.6.8	2021-10-03
stringr	1.4.0	2019-02-10
tibble	3.1.6	2021-11-07
tidyr	1.1.4	2021-09-27
tidyverse	1.3.1	2021-04-15
waterData	1.0.8	2017-04-28