

Appendix S1. Instructions for retrieving and archiving the environmental covariates.

Contents

1	Background	1
2	User inputs	2
3	Function definitions	2
4	Loading the fish data	3
5	Retrieve flow covariates	4
6	Correlation of covariates	5

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1 Background

This appendix describes how to retrieve the environmental covariates used in the analyses, and summarize them over the appropriate months and years. After reading in the raw data, summarizing them, and trimming them to the appropriate time frame, the table of covariates is written to a `.csv` file.

All of the analyses require the R software (v3.5 or later) for data retrieval and processing. You will also need several packages that are not included with the base installation of **R**.

```
if(!require("here")) {  
  install.packages("here")  
  library("here")  
}  
## set data dir  
datadir <- here("data")  
if(!require("EGRET")) {  
  install.packages("EGRET")  
  library("EGRET")  
}  
if(!require("corrplot")) {  
  install.packages("corrplot")  
  library("corrplot")  
}  
if(!require("captioner")) {  
  devtools::install_github("adletaw/captioner")  
}
```

```

  library("captioner")
}
fig_cap <- captioner(prefix = "Figure S", suffix = ". ",
                     style = "b", style_prefix = TRUE,
                     auto_space = FALSE)

```

2 User inputs

We begin by specifying

1. the name of the data file that contains the observed total number of adult spawners (escapement) by year; and
2. the minimum age of an adult spawner.

```

## [n_yrs x 2] matrix of obs counts; 1st col is calendar yr
fn_esc <- "chin_esc.csv"

## min adult age
age_min <- 3

```

Next we retrieve the metadata for the covariates from a .csv file with the following columns:

1. `spp`: the species to which the covariate applies
2. `life_stage`: life stage at which the effect is thought to occur
3. `covariate`: type of covariate (e.g., flow, temperature)
4. `code`: USGS code for data type (i.e., usually 5-digit integer)
5. `long_name`: long name for the covariate
6. `short_name`: function name to derive the covariate
7. `lag_1`: years to lag begin date
8. `lag_2`: years to lag end date
9. `begin`: beginning date as 2-digit text (ie, mo-yr)
10. `end`: ending date as 2-digit text (ie, mo-yr)
11. `location`: description of location
12. `gage`: USGS gage number
13. `flag`: flag to include (1) or exclude (0) the covariate
14. `flow_scen`: flag to include (1) or exclude (0) flow scenario
15. `group`: integer indicator for life stage grouping

```

## covariate metadata
cov_meta_file <- "chin_cov_metadata.csv"

```

3 Function definitions

```

## over90k
## returns the total number of days that flow exceeded 90k cfs
over90k <- function(x) {
  return(sum(x >= 90000))
}

```

```

}

## min7mean
## returns the min of 7-day means over period
min7mean <- function(x) {
  return(round(min(filter(x, rep(1,7)/7, "convolution", sides = 1),
                    na.rm = TRUE), 0))
}

## max7mean
## returns the max of 7-day means over period
max7mean <- function(x) {
  return(round(max(filter(x, rep(1,7)/7, "convolution", sides = 1),
                    na.rm = TRUE), 0))
}

## med7mean
## returns the max of 7-day means over period
med7mean <- function(x) {
  return(round(median(filter(x, rep(1,7)/7, "convolution", sides = 1),
                        na.rm = TRUE), 0))
}

## rng7mean
## returns the max of 7-day means over period
rng7mean <- function(x) {
  return(round(diff(range(filter(x, rep(1,7)/7, "convolution", sides = 1),
                        na.rm = TRUE)), 0))
}

## range2
## returns the range as a scalar = max-min
range2 <- function(x) {
  return(diff(range(x)))
}

```

4 Loading the fish data

We begin by loading the spawner data so we can get the time frame of interest for the covariates.

```

## escapement
dat_esc <- read.csv(file.path(datadir,fn_esc))

## get first & last years
yr_frst <- min(dat_esc$year)
yr_last <- max(dat_esc$year)

```

5 Retrieve flow covariates

The analyses are based upon several environmental indicators related to river discharge. Load the metadata file containing all of the specifications for the covariates to be used.

```
cov_meta <- read.csv(file.path(datadir, cov_meta_file), stringsAsFactors = FALSE)
cov_meta$code <- gsub("\\", "", cov_meta$code)
cov_meta$begin <- gsub("\\", "", cov_meta$begin)
cov_meta$end <- gsub("\\", "", cov_meta$end)
```

We need to define the beginning and ending dates for the covariates.

```
yr1 <- yr_first
yr2 <- yr_last - age_min
## start date
startDate <- paste0(yr1 + min(cov_meta$lag_1), "-01-01")
## end date
endDate <- paste0(yr2 + max(cov_meta$lag_2), "-12-31")
```

We begin by getting the daily flow data from the US Geological Service National Water Information System for the complete time period of interest.

```
## metadata for flow covariates
flow_meta <- subset(cov_meta, covariate=="flow" & flag==1)
## data to get: flow (cfs)
parameterCD <- "00060"
## get all flow data for period of interest & gages
gages <- unique(flow_meta$gage)
n_gages <- length(gages)
tmp <- readNWISDaily(gages[1], parameterCD, startDate, endDate, convert=FALSE)
tmp$yr <- floor(tmp$DecYear)
flow_data <- tmp[,c("Date", "waterYear", "yr", "Month", "Day")]
colnames(flow_data) <- c("date", "H2Oyr", "yr", "mon", "day")
flow_data[,as.character(gages[1])] <- tmp$Q
if(n_gages > 1) {
  for(i in 2:n_gages) {
    tmp <- readNWISDaily(gages[i], parameterCD, startDate, endDate, convert=FALSE)
    flow_data[,as.character(gages[i])] <- tmp$Q
  }
}
```

There are 6940 data points, and 6940 days.

Now we can extract the specific flow covariates that relate to each of the hypotheses about the affected life stage.

```
cov_flow <- matrix(NA, length(seq(yr1, yr2)), dim(flow_meta)[1]+1)
n_mods <- dim(cov_flow)[2] - 1
cov_flow[,1] <- seq(yr_first, yr2)
for(i in 1:dim(flow_meta)[1]) {
  fn <- get(flow_meta[i, "short_name"])
```

```

cnt <- 1
for(t in yr1:yr2) {
  beg <- paste0(t+flow_meta[i,"lag_1"], "-", flow_meta[i,"begin"])
  end <- paste0(t+flow_meta[i,"lag_2"], "-", flow_meta[i,"end"])
  tmp <- flow_data[flow_data$date>=beg & flow_data$date<=end,
                  as.character(flow_meta[i,"gage"])]
  cov_flow[cnt,i+1] <- fn(tmp)
  cnt <- cnt+1
}
}
## write flow covariates to file
write.csv(cov_flow, row.names = FALSE,
          file = file.path(datadir,
                           "Willamette_Chin_SR_mainstem_flow_covariates.csv"))

```

6 Correlation of covariates

Below is a graphical representation of the pairwise correlation between each of the 32 flow covariates.

```

par(mai=rep(0.1, 4), omi=rep(0.1, 4))
corrplot(cor(cov_flow[, -1]), method="ellipse", type="lower",
          tl.col = "black", tl.srt = 0, tl.cex = 0.5, tl.offset = 0.7,
          cl.cex = 0.8, cl.offset = 0.9, cl.ratio = 0.2)

```

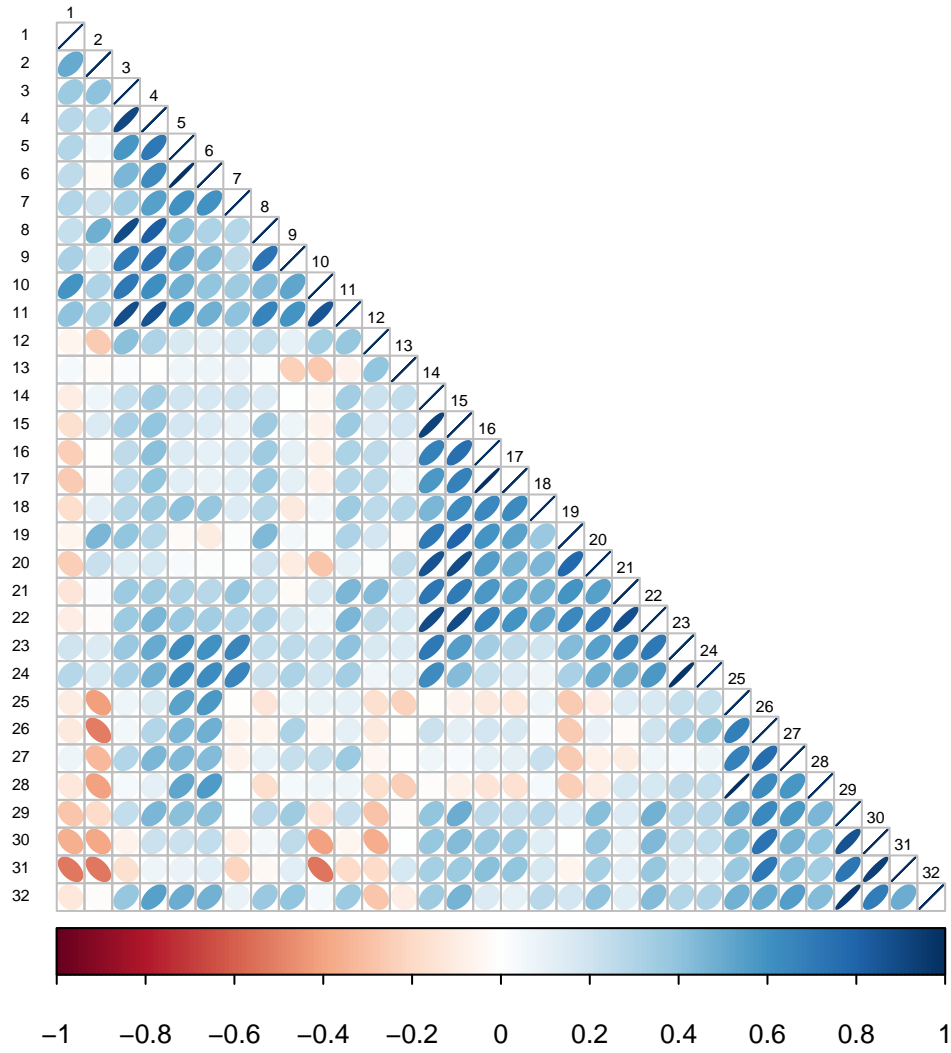


Figure S1. Pairwise correlation for each of the 32 flow covariates considered in the analysis.