

SURE Project

August 29, 2022

Objective

Predict and project spatially the result from the models.

```
## Script by Anita Giraldo, 4 May 2022
## Last modified by Anita Giraldo, 4 May 2022

# Clear environment ----
rm(list=ls())

# directories ----
m.dir <- here()
d.dir <- here('data')
k.dir <- here('outputs_nc_rcca')
o.dir <- paste(k.dir, "gam_V5", sep = '/') # kelp model results
u.dir <- paste(k.dir, "gam_urchins3", sep = '/') # urchin model results
rcca.dir <- "G:/Shared drives/California Kelp Restoration Project - Seagrant/R_Projects/North_Coast_w_R
dd.dir <- "G:/Shared drives/California Kelp Restoration Project - Seagrant/R_Projects/Extract_env_data/

## Load info on years RCCA ----
years <- read.csv(paste(d.dir, "RCCA_North_Coast_sites.csv", sep = '/')) %>%
  glimpse() # Rows: 25
```

```
## Rows: 25
## Columns: 7
## $ site_name      <chr> "Caspar", "Caspar North", "Dark Gulch", "Flat Iron Ro~
## $ total.years    <int> 10, 8, 1, 2, 15, 8, 16, 4, 4, 13, 3, 14, 6, 4, 7, 8, ~
## $ pre.mhw.years  <int> 2, NA, NA, NA, 7, NA, 8, NA, NA, 6, NA, 6, NA, NA, 3, ~
## $ during.mhw.years <int> 3, 3, NA, NA, 3, 3, 3, 1, NA, 3, NA, 3, 2, NA, 1, 1, ~
## $ post.mhw.years  <int> 5, 5, 1, 3, 5, 5, 5, 3, 4, 4, 3, 5, 4, 4, 3, 4, 5, 3, ~
## $ longitude      <dbl> -123.8220, -123.8213, -123.7762, -124.1578, -123.2450~
## $ latitude       <dbl> 39.36173, 39.36443, 39.24030, 41.05942, 38.51060, 39.~
```

```
# get the sites from with preMHW data ----
# 3 or more pre MHW surveys
ncsites <- years %>%
  mutate_at(vars(site_name), list(as.factor)) %>%
  # get only sites with PRE MHW data
  dplyr::filter(pre.mhw.years > 2) %>%
  droplevels() %>%
  glimpse() # Rows: 64
```

```
## Rows: 10
```

```
## Columns: 7
## $ site_name      <fct> Fort Ross, Gerstle Cove, Mendocino Headlands, Ocean C-
## $ total.years    <int> 15, 16, 13, 14, 7, 8, 12, 15, 3, 15
## $ pre.mhw.years  <int> 7, 8, 6, 6, 3, 3, 6, 7, 3, 7
## $ during.mhw.years <int> 3, 3, 3, 3, 1, 1, 1, 3, NA, 3
## $ post.mhw.years <int> 5, 5, 4, 5, 3, 4, 5, 5, NA, 5
## $ longitude      <dbl> -123.2450, -123.3300, -123.8110, -123.3057, -123.7410~
## $ latitude       <dbl> 38.51060, 38.56646, 39.30528, 38.55512, 38.94480, 38.~
```

1. Load RCCA data

```
df <- read.csv(paste(d.dir, "RCCA_kelp_inverts_NC_depth-zones_wave_clim_temp_nit_subs_orbvel_npp.csv", ))
mutate_at(vars(site_name, month, year, transect, zone), list(as.factor)) %>%
mutate(zone_new = case_when(
  transect == '1' ~ 'OUTER',
  transect == '2' ~ 'OUTER',
  transect == '3' ~ 'OUTER',
  transect == '4' ~ 'INNER',
  transect == '5' ~ 'INNER',
  transect == '6' ~ 'INNER')) %>%
dplyr::select(-zone) %>%
rename(zone = zone_new) %>%
mutate_at(vars(zone), list(as.factor)) %>%
relocate(zone, .after = transect) %>%
glimpse() # Rows: 1,154
```

```
## Rows: 1,154
## Columns: 152
## $ site_name      <fct> Caspar, Caspar, Caspar, Caspar, ~
## $ month          <fct> 6, 6, 6, 6, 6, 6, 8, 8, 8, 8, ~
## $ year           <fct> 2018, 2018, 2018, 2018, 2018, 20~
## $ transect       <fct> 1, 2, 3, 4, 5, 6, 1, 2, 3, 4, 5, ~
## $ zone           <fct> OUTER, OUTER, OUTER, INNER, INNE~
## $ latitude       <dbl> 39.36173, 39.36173, 39.36173, 39~
## $ longitude      <dbl> -123.822, -123.822, -123.822, -1~
## $ den_STRPURAD    <dbl> 37.0000, 184.6154, 52.0000, 22.0~
## $ den_HALRUF      <dbl> 12, 3, 0, 0, 2, 3, 16, 19, 27, 1~
## $ den_MESFRAAD    <dbl> 102.00000, 27.00000, 193.33333, ~
## $ den_PYCHEL      <int> 0, 0, 0, 0, 0, 0, 1, 0, 4, 1, 0, ~
## $ den_NERLUE      <dbl> 0.00000, 0.00000, 0.00000, 0.000~
## $ den_MACPYRAD    <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## $ den_NERLUEsmall <int> NA, NA, NA, NA, NA, NA, NA, NA, ~
## $ den_MACSTIPES   <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## $ npp.mean        <dbl> 1364.5333, 1364.5333, 1364.5333, ~
## $ pdo_mean        <dbl> -0.3625000, -0.3625000, -0.36250~
## $ npgo_mean       <dbl> -1.9050000, -1.9050000, -1.90500~
## $ mei_mean        <dbl> -0.2916667, -0.2916667, -0.29166~
## $ Days_15C        <int> 4, 4, 4, 4, 4, 4, 0, 0, 0, 0, 0, ~
## $ Days_16C        <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## $ Days_17C        <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## $ Days_18C        <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## $ Days_19C        <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
```

## \$ Days_20C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## \$ Days_21C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## \$ Days_22C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## \$ Days_23C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## \$ Degree_Days_15C	<dbl> 1.03, 1.03, 1.03, 1.03, 1.03, 1.~
## \$ Degree_Days_16C	<dbl> 0.00, 0.00, 0.00, 0.00, 0.00, 0.~
## \$ Degree_Days_17C	<dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## \$ Degree_Days_18C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## \$ Degree_Days_19C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## \$ Degree_Days_20C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## \$ Degree_Days_21C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## \$ Degree_Days_22C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## \$ Degree_Days_23C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## \$ Max_Monthly_Anomaly_Summer_Temp	<dbl> 0.9405405, 0.9405405, 0.9405405, ~
## \$ Max_Monthly_Anomaly_Temp	<dbl> 1.2088579, 1.2088579, 1.2088579, ~
## \$ Max_Monthly_Anomaly_Upwelling_Temp	<dbl> 0.4936126, 0.4936126, 0.4936126, ~
## \$ Max_Monthly_Temp_Index	<int> 10, 10, 10, 10, 10, 10, 9, 9, 9, ~
## \$ Max_Monthly_Temp	<dbl> 13.42419, 13.42419, 13.42419, 13~
## \$ Mean_Monthly_Summer_Temp	<dbl> 12.26695, 12.26695, 12.26695, 12~
## \$ Mean_Monthly_Temp	<dbl> 11.87421, 11.87421, 11.87421, 11~
## \$ Mean_Monthly_Upwelling_Temp	<dbl> 10.941999, 10.941999, 10.941999, ~
## \$ MHW_Days	<int> 27, 27, 27, 27, 27, 27, 0, 0, 0, ~
## \$ MHW_Intensity	<dbl> 55.82227, 55.82227, 55.82227, 55~
## \$ MHW_Summer_Days	<int> 17, 17, 17, 17, 17, 17, 0, 0, 0, ~
## \$ MHW_Summer_Intensity	<dbl> 38.47348, 38.47348, 38.47348, 38~
## \$ MHW_Upwelling_Days	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## \$ MHW_Upwelling_Intensity	<dbl> 0.00000, 0.00000, 0.00000, 0.000~
## \$ Min_Monthly_Anomaly_Summer_Temp	<dbl> -0.7582432, -0.7582432, -0.75824~
## \$ Min_Monthly_Anomaly_Temp	<dbl> -0.7670180, -0.7670180, -0.76701~
## \$ Min_Monthly_Anomaly_Upwelling_Temp	<dbl> -0.1944892, -0.1944892, -0.19448~
## \$ Min_Monthly_Temp_Index	<int> 6, 6, 6, 6, 6, 6, 5, 5, 5, 5, 5, ~
## \$ Min_Monthly_Temp	<dbl> 10.361333, 10.361333, 10.361333, ~
## \$ Days_10N	<int> 70, 70, 70, 70, 70, 70, 91, 91, ~
## \$ Days_11N	<int> 64, 64, 64, 64, 64, 64, 79, 79, ~
## \$ Days_12N	<int> 57, 57, 57, 57, 57, 57, 73, 73, ~
## \$ Days_13N	<int> 49, 49, 49, 49, 49, 49, 66, 66, ~
## \$ Days_14N	<int> 40, 40, 40, 40, 40, 40, 57, 57, ~
## \$ Days_15N	<int> 38, 38, 38, 38, 38, 38, 52, 52, ~
## \$ Days_1N	<int> 198, 198, 198, 198, 198, 198, 31~
## \$ Days_2N	<int> 181, 181, 181, 181, 181, 181, 27~
## \$ Days_3N	<int> 160, 160, 160, 160, 160, 160, 22~
## \$ Days_4N	<int> 139, 139, 139, 139, 139, 139, 18~
## \$ Days_5N	<int> 127, 127, 127, 127, 127, 127, 16~
## \$ Days_6N	<int> 111, 111, 111, 111, 111, 111, 14~
## \$ Days_7N	<int> 103, 103, 103, 103, 103, 103, 12~
## \$ Days_8N	<int> 90, 90, 90, 90, 90, 90, 115, 115~
## \$ Days_9N	<int> 82, 82, 82, 82, 82, 82, 103, 103~
## \$ Degree_Days_10N	<dbl> 380.72462, 380.72462, 380.72462, ~
## \$ Degree_Days_11N	<dbl> 313.86470, 313.86470, 313.86470, ~
## \$ Degree_Days_12N	<dbl> 253.03910, 253.03910, 253.03910, ~
## \$ Degree_Days_13N	<dbl> 200.88361, 200.88361, 200.88361, ~
## \$ Degree_Days_14N	<dbl> 156.60688, 156.60688, 156.60688, ~
## \$ Degree_Days_15N	<dbl> 117.571951, 117.571951, 117.5719~
## \$ Degree_Days_1N	<dbl> 1513.3439, 1513.3439, 1513.3439, ~

```

## $ Degree_Days_2N <dbl> 1324.2269, 1324.2269, 1324.2269,~
## $ Degree_Days_3N <dbl> 1151.4363, 1151.4363, 1151.4363,~
## $ Degree_Days_4N <dbl> 998.3203, 998.3203, 998.3203, 99~
## $ Degree_Days_5N <dbl> 865.9663, 865.9663, 865.9663, 86~
## $ Degree_Days_6N <dbl> 746.4577, 746.4577, 746.4577, 74~
## $ Degree_Days_7N <dbl> 638.4387, 638.4387, 638.4387, 63~
## $ Degree_Days_8N <dbl> 542.5561, 542.5561, 542.5561, 54~
## $ Degree_Days_9N <dbl> 456.72968, 456.72968, 456.72968,~
## $ Max_Monthly_Anomaly_Nitrate <dbl> 3.9860960, 3.9860960, 3.9860960,~
## $ Max_Monthly_Anomaly_Summer_Nitrate <dbl> 3.9860960, 3.9860960, 3.9860960,~
## $ Max_Monthly_Anomaly_Upwelling_Nitrate <dbl> 0.5618353, 0.5618353, 0.5618353,~
## $ Max_Monthly_Nitrate_Index <int> 6, 6, 6, 6, 6, 6, 5, 5, 5, 5, 5,~
## $ Max_Monthly_Nitrate <dbl> 13.392856, 13.392856, 13.392856,~
## $ Mean_Monthly_Nitrate <dbl> 4.787915, 4.787915, 4.787915, 4.~
## $ Mean_Monthly_Summer_Nitrate <dbl> 3.754989, 3.754989, 3.754989, 3.~
## $ Mean_Monthly_Upwelling_Nitrate <dbl> 8.908040, 8.908040, 8.908040, 8.~
## $ Min_Monthly_Anomaly_Nitrate <dbl> -5.353170, -5.353170, -5.353170,~
## $ Min_Monthly_Anomaly_Summer_Nitrate <dbl> -2.33496107, -2.33496107, -2.334~
## $ Min_Monthly_Anomaly_Upwelling_Nitrate <dbl> -4.242842, -4.242842, -4.242842,~
## $ Min_Monthly_Nitrate <dbl> 0.8870311, 0.8870311, 0.8870311,~
## $ Min_Monthly_Temp_Nitrate <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,~
## $ mean_depth <dbl> -0.5695702, -0.5695702, -0.56957~
## $ mean_prob_of_rock <dbl> 0.9997463, 0.9997463, 0.9997463,~
## $ mean_vrm <dbl> 8.62e-05, 8.62e-05, 8.62e-05, 8.~
## $ mean_slope <dbl> 0.8211701, 0.8211701, 0.8211701,~
## $ sd_depth <dbl> 1.106474, 1.106474, 1.106474, 1.~
## $ sd_prob_of_rock <dbl> 0.001056774, 0.001056774, 0.0010~
## $ sd_vrm <dbl> 0.00029503, 0.00029503, 0.000295~
## $ sd_slope <dbl> 1.729309, 1.729309, 1.729309, 1.~
## $ min_depth <dbl> -4.259407, -4.259407, -4.259407,~
## $ min_prob_of_rock <dbl> 0.9947428, 0.9947428, 0.9947428,~
## $ min_vrm <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ min_slope <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ max_depth <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ max_prob_of_rock <dbl> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,~
## $ max_vrm <dbl> 0.003624092, 0.003624092, 0.0036~
## $ max_slope <dbl> 8.586119, 8.586119, 8.586119, 8.~
## $ range_depth <dbl> 4.259407, 4.259407, 4.259407, 4.~
## $ range_prob_of_rock <dbl> 0.005257189, 0.005257189, 0.0052~
## $ range_vrm <dbl> 0.003624092, 0.003624092, 0.0036~
## $ range_slope <dbl> 8.586119, 8.586119, 8.586119, 8.~
## $ median_depth <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ median_prob_of_rock <dbl> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,~
## $ median_vrm <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ median_slope <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ prop_map_depth <dbl> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,~
## $ prop_map_prob_of_rock <dbl> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,~
## $ prop_map_vrm <dbl> 0.5717566, 0.5717566, 0.5717566,~
## $ prop_map_slope <dbl> 0.6613088, 0.6613088, 0.6613088,~
## $ wh_mean <dbl> 0.9742126, 0.9742126, 0.9742126,~
## $ wh_max <dbl> 2.699128, 2.699128, 2.699128, 2.~
## $ wh_95prc <dbl> 1.624681, 1.624681, 1.624681, 1.~
## $ wh_99prc <dbl> 2.105916, 2.105916, 2.105916, 2.~
## $ mean_waveyear <dbl> 1.0328991, 1.0328991, 1.0328991,~

```

```
## $ max_waveyear <dbl> 2.699128, 2.699128, 2.699128, 2.~
## $ wh_95prc_wy <dbl> 1.718803, 1.718803, 1.718803, 1.~
## $ wh_99prc_wy <dbl> 2.079910, 2.079910, 2.079910, 2.~
## $ UBR_Max <int> 467, 467, 467, 467, 467, 467, 38~
## $ UBR_Mean <int> 155, 155, 155, 155, 155, 155, 23~
## $ UBRYear_Max <int> 467, 467, 467, 467, 467, 467, 38~
## $ UBRYear_Mean <int> 232, 232, 232, 232, 232, 232, 23~
## $ Wave_Max <int> 3, 3, 3, 3, 3, 3, 2, 2, 2, 2, 2,~
## $ Wave_Mean <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,~
## $ WaveYear_Max <int> 3, 3, 3, 3, 3, 3, 2, 2, 2, 2, 2,~
## $ WaveYear_Mean <int> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,~
## $ Max_Monthly_NPP <dbl> 5792.267, 5792.267, 5792.267, 57~
## $ Max_Monthly_NPP_Summer <dbl> 5792.267, 5792.267, 5792.267, 57~
## $ Max_Monthly_NPP_Upwelling <dbl> 3045.315, 3045.315, 3045.315, 30~
## $ Mean_Monthly_NPP <dbl> 2106.831, 2106.831, 2106.831, 21~
## $ Mean_Monthly_NPP_Summer <dbl> 2924.500, 2924.500, 2924.500, 29~
## $ Mean_Monthly_NPP_Upwelling <dbl> 1781.252, 1781.252, 1781.252, 17~
## $ Min_Monthly_NPP <dbl> 698.8677, 698.8677, 698.8677, 69~
## $ Min_Monthly_NPP_Summer <dbl> 1255.6813, 1255.6813, 1255.6813,~
## $ Min_Monthly_NPP_Upwelling <dbl> 927.1774, 927.1774, 927.1774, 92~
```

```
## get the sites for North Coast model ----
```

```
df.nc <- df %>%
  dplyr::select(-c(latitude, longitude)) %>%
  right_join(ncsites, by = c('site_name')) %>%
  droplevels() %>% #glimpse()
  #dplyr::select(-c(total.years, pre.mhw.years, during.mhw.years, post.mhw.years)) %>%
  relocate(c(latitude, longitude), .after = zone) %>%
  glimpse() # Rows: 708
```

```
## Rows: 708
## Columns: 156
## $ site_name <fct> Fort Ross, Fort Ross, Fort Ross,~
## $ month <fct> 10, 10, 10, 10, 10, 10, 10, ~
## $ year <fct> 2015, 2015, 2015, 2015, 2015, 20~
## $ transect <fct> 1, 2, 3, 4, 5, 6, 1, 2, 3, 4, 5,~
## $ zone <fct> OUTER, OUTER, OUTER, INNER, INNE~
## $ latitude <dbl> 38.5106, 38.5106, 38.5106, 38.51~
## $ longitude <dbl> -123.245, -123.245, -123.245, -1~
## $ den_STRPURAD <dbl> 55.55556, 20.00000, 750.00000, 5~
## $ den_HALRUF <dbl> 55.55556, 9.00000, 50.00000, 55.~
## $ den_MESFRAAD <dbl> 46.00000, 55.55556, 7.00000, 35.~
## $ den_PYCHEL <int> 0, 0, 0, 0, 0, 0, 0, 6, 0, 0, 2,~
## $ den_NERLUE <dbl> 0.00000, 0.00000, 0.00000, 0.000~
## $ den_MACPYRAD <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ den_NERLUEsmall <int> NA, NA, NA, NA, NA, NA, NA, NA, ~
## $ den_MACSTIPES <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ npp.mean <dbl> NA, NA, NA, NA, NA, NA, 1133.195~
## $ pdo_mean <dbl> 0.920000, 0.920000, 0.920000, 0.~
## $ npgo_mean <dbl> -1.3941667, -1.3941667, -1.39416~
## $ mei_mean <dbl> 1.28333333, 1.28333333, 1.283333~
## $ Days_15C <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ Days_16C <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ Days_17C <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
```

## \$ Days_18C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_19C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_20C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_21C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_22C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_23C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Degree_Days_15C	<dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Degree_Days_16C	<dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Degree_Days_17C	<dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Degree_Days_18C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Degree_Days_19C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Degree_Days_20C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Degree_Days_21C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Degree_Days_22C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Degree_Days_23C	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Max_Monthly_Anomaly_Summer_Temp	<dbl> 2.86037489, 2.86037489, 2.860374~
## \$ Max_Monthly_Anomaly_Temp	<dbl> 2.85233653, 2.85233653, 2.852336~
## \$ Max_Monthly_Anomaly_Upwelling_Temp	<dbl> 2.0442495, 2.0442495, 2.0442495,~
## \$ Max_Monthly_Temp_Index	<int> 10, 10, 10, 10, 10, 10, 9, 9, 9,~
## \$ Max_Monthly_Temp	<dbl> 15.56290, 15.56290, 15.56290, 15~
## \$ Mean_Monthly_Summer_Temp	<dbl> 14.04160, 14.04160, 14.04160, 14~
## \$ Mean_Monthly_Temp	<dbl> 12.93553, 12.93553, 12.93553, 12~
## \$ Mean_Monthly_Upwelling_Temp	<dbl> 11.597677, 11.597677, 11.597677,~
## \$ MHW_Days	<int> 167, 167, 167, 167, 167, 167, 5,~
## \$ MHW_Intensity	<dbl> 384.061512, 384.061512, 384.0615~
## \$ MHW_Summer_Days	<int> 94, 94, 94, 94, 94, 94, 5, 5, 5,~
## \$ MHW_Summer_Intensity	<dbl> 250.955777, 250.955777, 250.9557~
## \$ MHW_Upwelling_Days	<int> 33, 33, 33, 33, 33, 33, 0, 0, 0,~
## \$ MHW_Upwelling_Intensity	<dbl> 68.16678, 68.16678, 68.16678, 68~
## \$ Min_Monthly_Anomaly_Summer_Temp	<dbl> 0.7928108, 0.7928108, 0.7928108,~
## \$ Min_Monthly_Anomaly_Temp	<dbl> -0.05073234, -0.05073234, -0.050~
## \$ Min_Monthly_Anomaly_Upwelling_Temp	<dbl> -0.04973845, -0.04973845, -0.049~
## \$ Min_Monthly_Temp_Index	<int> 5, 5, 5, 5, 5, 5, 4, 4, 4, 4, 4,~
## \$ Min_Monthly_Temp	<dbl> 10.129032, 10.129032, 10.129032,~
## \$ Days_10N	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_11N	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_12N	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_13N	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_14N	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_15N	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_1N	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_2N	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_3N	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_4N	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_5N	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_6N	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_7N	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_8N	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Days_9N	<int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Degree_Days_10N	<dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Degree_Days_11N	<dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Degree_Days_12N	<dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Degree_Days_13N	<dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## \$ Degree_Days_14N	<dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~

```

## $ Degree_Days_15N <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ Degree_Days_1N <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ Degree_Days_2N <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ Degree_Days_3N <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ Degree_Days_4N <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ Degree_Days_5N <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ Degree_Days_6N <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ Degree_Days_7N <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ Degree_Days_8N <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ Degree_Days_9N <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ Max_Monthly_Anomaly_Nitrate <dbl> 0.4776073, 0.4776073, 0.4776073,~
## $ Max_Monthly_Anomaly_Summer_Nitrate <dbl> -0.4975728, -0.4975728, -0.49757~
## $ Max_Monthly_Anomaly_Upwelling_Nitrate <dbl> 0.4776073, 0.4776073, 0.4776073,~
## $ Max_Monthly_Nitrate_Index <int> 5, 5, 5, 5, 5, 5, 4, 4, 4, 4, 4,~
## $ Max_Monthly_Nitrate <dbl> 15.50432, 15.50432, 15.50432, 15~
## $ Mean_Monthly_Nitrate <dbl> 2.951467, 2.951467, 2.951467, 2.~
## $ Mean_Monthly_Summer_Nitrate <dbl> 1.290271, 1.290271, 1.290271, 1.~
## $ Mean_Monthly_Upwelling_Nitrate <dbl> 7.056086, 7.056086, 7.056086, 7.~
## $ Min_Monthly_Anomaly_Nitrate <dbl> -8.0158185, -8.0158185, -8.01581~
## $ Min_Monthly_Anomaly_Summer_Nitrate <dbl> -6.5534900, -6.5534900, -6.55349~
## $ Min_Monthly_Anomaly_Upwelling_Nitrate <dbl> -8.015819, -8.015819, -8.015819,~
## $ Min_Monthly_Nitrate <dbl> 0.0000000, 0.0000000, 0.0000000,~
## $ Min_Monthly_Temp_Nitrate <int> 1, 1, 1, 1, 1, 1, 6, 6, 6, 6, 6,~
## $ mean_depth <dbl> -9.040727, -9.040727, -9.040727,~
## $ mean_prob_of_rock <dbl> 0.6323734, 0.6323734, 0.6323734,~
## $ mean_vrm <dbl> 0.000137088, 0.000137088, 0.0001~
## $ mean_slope <dbl> 3.476603, 3.476603, 3.476603, 3.~
## $ sd_depth <dbl> 3.48555, 3.48555, 3.48555, 3.485~
## $ sd_prob_of_rock <dbl> 0.3317136, 0.3317136, 0.3317136,~
## $ sd_vrm <dbl> 0.000209537, 0.000209537, 0.0002~
## $ sd_slope <dbl> 0.7030445, 0.7030445, 0.7030445,~
## $ min_depth <dbl> -16.12281, -16.12281, -16.12281,~
## $ min_prob_of_rock <dbl> 5.66e-05, 5.66e-05, 5.66e-05, 5.~
## $ min_vrm <dbl> 1.34e-05, 1.34e-05, 1.34e-05, 1.~
## $ min_slope <dbl> 1.867539, 1.867539, 1.867539, 1.~
## $ max_depth <dbl> -2.433142, -2.433142, -2.433142,~
## $ max_prob_of_rock <dbl> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,~
## $ max_vrm <dbl> 0.000919998, 0.000919998, 0.0009~
## $ max_slope <dbl> 5.07899, 5.07899, 5.07899, 5.078~
## $ range_depth <dbl> 13.68967, 13.68967, 13.68967, 13~
## $ range_prob_of_rock <dbl> 0.9999434, 0.9999434, 0.9999434,~
## $ range_vrm <dbl> 0.000906646, 0.000906646, 0.0009~
## $ range_slope <dbl> 3.211451, 3.211451, 3.211451, 3.~
## $ median_depth <dbl> -8.798749, -8.798749, -8.798749,~
## $ median_prob_of_rock <dbl> 0.6991448, 0.6991448, 0.6991448,~
## $ median_vrm <dbl> 7.13e-05, 7.13e-05, 7.13e-05, 7.~
## $ median_slope <dbl> 3.382058, 3.382058, 3.382058, 3.~
## $ prop_map_depth <dbl> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,~
## $ prop_map_prob_of_rock <dbl> 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,~
## $ prop_map_vrm <dbl> 0.4444444, 0.4444444, 0.4444444,~
## $ prop_map_slope <dbl> 0.6666667, 0.6666667, 0.6666667,~
## $ wh_mean <dbl> 1.406087, 1.406087, 1.406087, 1.~
## $ wh_max <dbl> 6.918628, 6.918628, 6.918628, 6.~
## $ wh_95prc <dbl> 2.832922, 2.832922, 2.832922, 2.~

```

```
## $ wh_99prc <dbl> 4.722291, 4.722291, 4.722291, 4.~
## $ mean_waveyear <dbl> 1.731754, 1.731754, 1.731754, 1.~
## $ max_waveyear <dbl> 4.779284, 4.779284, 4.779284, 4.~
## $ wh_95prc_wy <dbl> 3.555114, 3.555114, 3.555114, 3.~
## $ wh_99prc_wy <dbl> 4.290092, 4.290092, 4.290092, 4.~
## $ UBR_Max <int> 243, 243, 243, 243, 243, 243, 13~
## $ UBR_Mean <int> 50, 50, 50, 50, 50, 50, 65, 65, ~
## $ UBRYear_Max <int> 163, 163, 163, 163, 163, 163, 13~
## $ UBRYear_Mean <int> 67, 67, 67, 67, 67, 67, 65, 65, ~
## $ Wave_Max <int> 7, 7, 7, 7, 7, 7, 4, 4, 4, 4, 4,~
## $ Wave_Mean <int> 1, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2,~
## $ WaveYear_Max <int> 5, 5, 5, 5, 5, 5, 4, 4, 4, 4, 4,~
## $ WaveYear_Mean <int> 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2,~
## $ Max_Monthly_NPP <dbl> 7337.850, 7337.850, 7337.850, 73~
## $ Max_Monthly_NPP_Summer <dbl> 7337.850, 7337.850, 7337.850, 73~
## $ Max_Monthly_NPP_Upwelling <dbl> 5837.788, 5837.788, 5837.788, 58~
## $ Mean_Monthly_NPP <dbl> 3014.864, 3014.864, 3014.864, 30~
## $ Mean_Monthly_NPP_Summer <dbl> 3491.858, 3491.858, 3491.858, 34~
## $ Mean_Monthly_NPP_Upwelling <dbl> 3246.272, 3246.272, 3246.272, 32~
## $ Min_Monthly_NPP <dbl> 984.9625, 984.9625, 984.9625, 98~
## $ Min_Monthly_NPP_Summer <dbl> 1313.652, 1313.652, 1313.652, 13~
## $ Min_Monthly_NPP_Upwelling <dbl> 1300.4202, 1300.4202, 1300.4202,~
## $ total.years <int> 15, 15, 15, 15, 15, 15, 15, 15, ~
## $ pre.mhw.years <int> 7, 7, 7, 7, 7, 7, 7, 7, 7, 7, ~
## $ during.mhw.years <int> 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, ~
## $ post.mhw.years <int> 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, ~
```

```
length(levels(df.nc$site_name)) # 10
```

```
## [1] 10
```

```
levels(df.nc$site_name)
```

```
## [1] "Fort Ross" "Gerstle Cove" "Mendocino Headlands"
## [4] "Ocean Cove" "Point Arena MPA (M2)" "Point Arena Ref"
## [7] "Portuguese Beach" "Stillwater Sonoma" "Stornetta"
## [10] "Van Damme"
```

```
any(is.na(df.nc$Max_Monthly_Anomaly_Temp)) # FALSE
```

```
## [1] FALSE
```

2. Choose variables and transform needed

```
names(df.nc)
```

```
## [1] "site_name"
## [2] "month"
## [3] "year"
```



```

## [4] "transect"
## [5] "zone"
## [6] "latitude"
## [7] "longitude"
## [8] "den_STRPURAD"
## [9] "den_HALRUF"
## [10] "den_MESFRAAD"
## [11] "den_PYCHEL"
## [12] "den_NERLUE"
## [13] "den_MACPYRAD"
## [14] "den_NERLUEsmall"
## [15] "den_MACSTIPES"
## [16] "npp.mean"
## [17] "pdo_mean"
## [18] "npgo_mean"
## [19] "mei_mean"
## [20] "Days_15C"
## [21] "Days_16C"
## [22] "Days_17C"
## [23] "Days_18C"
## [24] "Days_19C"
## [25] "Days_20C"
## [26] "Days_21C"
## [27] "Days_22C"
## [28] "Days_23C"
## [29] "Degree_Days_15C"
## [30] "Degree_Days_16C"
## [31] "Degree_Days_17C"
## [32] "Degree_Days_18C"
## [33] "Degree_Days_19C"
## [34] "Degree_Days_20C"
## [35] "Degree_Days_21C"
## [36] "Degree_Days_22C"
## [37] "Degree_Days_23C"
## [38] "Max_Monthly_Anomaly_Summer_Temp"
## [39] "Max_Monthly_Anomaly_Temp"
## [40] "Max_Monthly_Anomaly_Upwelling_Temp"
## [41] "Max_Monthly_Temp_Index"
## [42] "Max_Monthly_Temp"
## [43] "Mean_Monthly_Summer_Temp"
## [44] "Mean_Monthly_Temp"
## [45] "Mean_Monthly_Upwelling_Temp"
## [46] "MHW_Days"
## [47] "MHW_Intensity"
## [48] "MHW_Summer_Days"
## [49] "MHW_Summer_Intensity"
## [50] "MHW_Upwelling_Days"
## [51] "MHW_Upwelling_Intensity"
## [52] "Min_Monthly_Anomaly_Summer_Temp"
## [53] "Min_Monthly_Anomaly_Temp"
## [54] "Min_Monthly_Anomaly_Upwelling_Temp"
## [55] "Min_Monthly_Temp_Index"
## [56] "Min_Monthly_Temp"
## [57] "Days_10N"

```

```

## [58] "Days_11N"
## [59] "Days_12N"
## [60] "Days_13N"
## [61] "Days_14N"
## [62] "Days_15N"
## [63] "Days_1N"
## [64] "Days_2N"
## [65] "Days_3N"
## [66] "Days_4N"
## [67] "Days_5N"
## [68] "Days_6N"
## [69] "Days_7N"
## [70] "Days_8N"
## [71] "Days_9N"
## [72] "Degree_Days_10N"
## [73] "Degree_Days_11N"
## [74] "Degree_Days_12N"
## [75] "Degree_Days_13N"
## [76] "Degree_Days_14N"
## [77] "Degree_Days_15N"
## [78] "Degree_Days_1N"
## [79] "Degree_Days_2N"
## [80] "Degree_Days_3N"
## [81] "Degree_Days_4N"
## [82] "Degree_Days_5N"
## [83] "Degree_Days_6N"
## [84] "Degree_Days_7N"
## [85] "Degree_Days_8N"
## [86] "Degree_Days_9N"
## [87] "Max_Monthly_Anomaly_Nitrate"
## [88] "Max_Monthly_Anomaly_Summer_Nitrate"
## [89] "Max_Monthly_Anomaly_Upwelling_Nitrate"
## [90] "Max_Monthly_Nitrate_Index"
## [91] "Max_Monthly_Nitrate"
## [92] "Mean_Monthly_Nitrate"
## [93] "Mean_Monthly_Summer_Nitrate"
## [94] "Mean_Monthly_Upwelling_Nitrate"
## [95] "Min_Monthly_Anomaly_Nitrate"
## [96] "Min_Monthly_Anomaly_Summer_Nitrate"
## [97] "Min_Monthly_Anomaly_Upwelling_Nitrate"
## [98] "Min_Monthly_Nitrate"
## [99] "Min_Monthly_Temp_Nitrate"
## [100] "mean_depth"
## [101] "mean_prob_of_rock"
## [102] "mean_vrm"
## [103] "mean_slope"
## [104] "sd_depth"
## [105] "sd_prob_of_rock"
## [106] "sd_vrm"
## [107] "sd_slope"
## [108] "min_depth"
## [109] "min_prob_of_rock"
## [110] "min_vrm"
## [111] "min_slope"

```

```

## [112] "max_depth"
## [113] "max_prob_of_rock"
## [114] "max_vrm"
## [115] "max_slope"
## [116] "range_depth"
## [117] "range_prob_of_rock"
## [118] "range_vrm"
## [119] "range_slope"
## [120] "median_depth"
## [121] "median_prob_of_rock"
## [122] "median_vrm"
## [123] "median_slope"
## [124] "prop_map_depth"
## [125] "prop_map_prob_of_rock"
## [126] "prop_map_vrm"
## [127] "prop_map_slope"
## [128] "wh_mean"
## [129] "wh_max"
## [130] "wh_95prc"
## [131] "wh_99prc"
## [132] "mean_waveyear"
## [133] "max_waveyear"
## [134] "wh_95prc_wy"
## [135] "wh_99prc_wy"
## [136] "UBR_Max"
## [137] "UBR_Mean"
## [138] "UBRYear_Max"
## [139] "UBRYear_Mean"
## [140] "Wave_Max"
## [141] "Wave_Mean"
## [142] "WaveYear_Max"
## [143] "WaveYear_Mean"
## [144] "Max_Monthly_NPP"
## [145] "Max_Monthly_NPP_Summer"
## [146] "Max_Monthly_NPP_Upwelling"
## [147] "Mean_Monthly_NPP"
## [148] "Mean_Monthly_NPP_Summer"
## [149] "Mean_Monthly_NPP_Upwelling"
## [150] "Min_Monthly_NPP"
## [151] "Min_Monthly_NPP_Summer"
## [152] "Min_Monthly_NPP_Upwelling"
## [153] "total.years"
## [154] "pre.mhw.years"
## [155] "during.mhw.years"
## [156] "post.mhw.years"

```

```

dat1 <- df.nc %>%
  dplyr::select(
    # Factors
    latitude, longitude,
    site_name, year, transect, zone,
    # Bio vars
    den_NERLUE , den_MESFRAAD , den_STRPURAD , den_PYCHEL, den_HALRUF,
    # Nitrate vars

```

```

Days_10N,
Min_Monthly_Nitrate,
Max_Monthly_Nitrate,
Mean_Monthly_Nitrate,
Mean_Monthly_Upwelling_Nitrate,
Max_Monthly_Anomaly_Nitrate,
Mean_Monthly_Summer_Nitrate,
# Temperature vars
Days_16C ,
Mean_Monthly_Temp ,
Mean_Monthly_Summer_Temp,
MHW_Upwelling_Days ,
Min_Monthly_Anomaly_Temp,
Max_Monthly_Anomaly_Upwelling_Temp,
Min_Monthly_Temp,
Mean_Monthly_Upwelling_Temp,
#wh.95 , wh.max,
npgo_mean , mei_mean,
# substrate
mean_depth, mean_prob_of_rock, mean_vrm, mean_slope,
# waves
wh_max, wh_mean, mean_waveyear, wh_95prc,
# Orb vel
UBR_Mean, UBR_Max,
# NPP
Mean_Monthly_NPP, Max_Monthly_NPP_Upwelling, Mean_Monthly_NPP_Upwelling, Min_Monthly_NPP,
) %>%
# Bio transformations
mutate(log_den_NERLUE = log(den_NERLUE + 1),
       log_den_MESFRAAD = log(den_MESFRAAD + 1),
       log_den_STRPURAD = log(den_STRPURAD + 1),
       log_den_PYCHEL = log(den_PYCHEL + 1),
       log_den_HALRUF = log(den_HALRUF + 1),
       log_mean_vrm = log(mean_vrm + 1)) %>%
dplyr::select(-c(den_NERLUE,
                 den_MESFRAAD,
                 den_STRPURAD,
                 den_PYCHEL,
                 den_HALRUF,
                 mean_vrm)) %>%
# Temperature transformations
mutate(log_Days_16C = log(Days_16C + 1)) %>%
dplyr::select(-c(Days_16C)) %>%
# Orb vel transformations
mutate(log_UBR_Mean = log(UBR_Mean + 1),
       log_UBR_Max = log(UBR_Max + 1)) %>%
dplyr::select(-c(UBR_Mean,
                 UBR_Max)) %>%
# NPP transformations
mutate(log_Mean_Monthly_NPP_Upwelling = log(Mean_Monthly_NPP_Upwelling + 1),
       log_Min_Monthly_NPP = log(Min_Monthly_NPP + 1)) %>%
dplyr::select(-c(Mean_Monthly_NPP_Upwelling,
                 Min_Monthly_NPP)) %>%

```

```
glimpse() # Rows: 708
```

```
## Rows: 708
## Columns: 42
## $ latitude      <dbl> 38.5106, 38.5106, 38.5106, 38.5106, ~
## $ longitude     <dbl> -123.245, -123.245, -123.245, -123.~
## $ site_name     <fct> Fort Ross, Fort Ross, Fort Ross, Fo~
## $ year          <fct> 2015, 2015, 2015, 2015, 2015, 2015, ~
## $ transect      <fct> 1, 2, 3, 4, 5, 6, 1, 2, 3, 4, 5, 6, ~
## $ zone          <fct> OUTER, OUTER, OUTER, INNER, INNER, ~
## $ Days_10N      <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## $ Min_Monthly_Nitrate <dbl> 0.0000000, 0.0000000, 0.0000000, 0.~
## $ Max_Monthly_Nitrate <dbl> 15.50432, 15.50432, 15.50432, 15.50~
## $ Mean_Monthly_Nitrate <dbl> 2.951467, 2.951467, 2.951467, 2.951~
## $ Mean_Monthly_Upwelling_Nitrate <dbl> 7.056086, 7.056086, 7.056086, 7.056~
## $ Max_Monthly_Anomaly_Nitrate <dbl> 0.4776073, 0.4776073, 0.4776073, 0.~
## $ Mean_Monthly_Summer_Nitrate <dbl> 1.290271, 1.290271, 1.290271, 1.290~
## $ Mean_Monthly_Temp <dbl> 12.93553, 12.93553, 12.93553, 12.93~
## $ Mean_Monthly_Summer_Temp <dbl> 14.04160, 14.04160, 14.04160, 14.04~
## $ MHW_Upwelling_Days <int> 33, 33, 33, 33, 33, 33, 0, 0, 0, 0, ~
## $ Min_Monthly_Anomaly_Temp <dbl> -0.05073234, -0.05073234, -0.050732~
## $ Max_Monthly_Anomaly_Upwelling_Temp <dbl> 2.0442495, 2.0442495, 2.0442495, 2.~
## $ Min_Monthly_Temp <dbl> 10.129032, 10.129032, 10.129032, 10~
## $ Mean_Monthly_Upwelling_Temp <dbl> 11.597677, 11.597677, 11.597677, 11~
## $ npgo_mean     <dbl> -1.3941667, -1.3941667, -1.3941667, ~
## $ mei_mean      <dbl> 1.28333333, 1.28333333, 1.28333333, ~
## $ mean_depth    <dbl> -9.040727, -9.040727, -9.040727, -9~
## $ mean_prob_of_rock <dbl> 0.6323734, 0.6323734, 0.6323734, 0.~
## $ mean_slope    <dbl> 3.476603, 3.476603, 3.476603, 3.476~
## $ wh_max        <dbl> 6.918628, 6.918628, 6.918628, 6.918~
## $ wh_mean       <dbl> 1.406087, 1.406087, 1.406087, 1.406~
## $ mean_waveyear <dbl> 1.731754, 1.731754, 1.731754, 1.731~
## $ wh_95prc      <dbl> 2.832922, 2.832922, 2.832922, 2.832~
## $ Mean_Monthly_NPP <dbl> 3014.864, 3014.864, 3014.864, 3014.~
## $ Max_Monthly_NPP_Upwelling <dbl> 5837.788, 5837.788, 5837.788, 5837.~
## $ log_den_NERLUE <dbl> 0.000000, 0.000000, 0.000000, 0.000~
## $ log_den_MESFRAAD <dbl> 3.8501476, 4.0352234, 2.0794415, 3.~
## $ log_den_STRPURAD <dbl> 4.0352234, 3.0445224, 6.6214057, 4.~
## $ log_den_PYCHEL <dbl> 0.0000000, 0.0000000, 0.0000000, 0.~
## $ log_den_HALRUF <dbl> 4.0352234, 2.3025851, 3.9318256, 4.~
## $ log_mean_vrm   <dbl> 0.0001370786, 0.0001370786, 0.00013~
## $ log_Days_16C   <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## $ log_UBR_Mean   <dbl> 3.931826, 3.931826, 3.931826, 3.931~
## $ log_UBR_Max    <dbl> 5.497168, 5.497168, 5.497168, 5.497~
## $ log_Mean_Monthly_NPP_Upwelling <dbl> 8.085571, 8.085571, 8.085571, 8.085~
## $ log_Min_Monthly_NPP <dbl> 6.893618, 6.893618, 6.893618, 6.893~
```

```
#### Drop NAs ----
```

```
dat2 <- dat1 %>%
  drop_na() %>%
  glimpse() # Rows: 686
```

```
## Rows: 686
```

```
## Columns: 42
## $ latitude <dbl> 38.5106, 38.5106, 38.5106, 38.5106,~
## $ longitude <dbl> -123.245, -123.245, -123.245, -123.~
## $ site_name <fct> Fort Ross, Fort Ross, Fort Ross, Fo~
## $ year <fct> 2015, 2015, 2015, 2015, 2015, 2015,~
## $ transect <fct> 1, 2, 3, 4, 5, 6, 1, 2, 3, 4, 5, 6,~
## $ zone <fct> OUTER, OUTER, OUTER, INNER, INNER, ~
## $ Days_10N <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ Min_Monthly_Nitrate <dbl> 0.0000000, 0.0000000, 0.0000000, 0.~
## $ Max_Monthly_Nitrate <dbl> 15.50432, 15.50432, 15.50432, 15.50~
## $ Mean_Monthly_Nitrate <dbl> 2.951467, 2.951467, 2.951467, 2.951~
## $ Mean_Monthly_Upwelling_Nitrate <dbl> 7.056086, 7.056086, 7.056086, 7.056~
## $ Max_Monthly_Anomaly_Nitrate <dbl> 0.4776073, 0.4776073, 0.4776073, 0.~
## $ Mean_Monthly_Summer_Nitrate <dbl> 1.290271, 1.290271, 1.290271, 1.290~
## $ Mean_Monthly_Temp <dbl> 12.93553, 12.93553, 12.93553, 12.93~
## $ Mean_Monthly_Summer_Temp <dbl> 14.04160, 14.04160, 14.04160, 14.04~
## $ MHW_Upwelling_Days <int> 33, 33, 33, 33, 33, 33, 0, 0, 0, 0,~
## $ Min_Monthly_Anomaly_Temp <dbl> -0.05073234, -0.05073234, -0.050732~
## $ Max_Monthly_Anomaly_Upwelling_Temp <dbl> 2.0442495, 2.0442495, 2.0442495, 2.~
## $ Min_Monthly_Temp <dbl> 10.129032, 10.129032, 10.129032, 10~
## $ Mean_Monthly_Upwelling_Temp <dbl> 11.597677, 11.597677, 11.597677, 11~
## $ npgo_mean <dbl> -1.3941667, -1.3941667, -1.3941667,~
## $ mei_mean <dbl> 1.28333333, 1.28333333, 1.28333333,~
## $ mean_depth <dbl> -9.040727, -9.040727, -9.040727, -9~
## $ mean_prob_of_rock <dbl> 0.6323734, 0.6323734, 0.6323734, 0.~
## $ mean_slope <dbl> 3.476603, 3.476603, 3.476603, 3.476~
## $ wh_max <dbl> 6.918628, 6.918628, 6.918628, 6.918~
## $ wh_mean <dbl> 1.406087, 1.406087, 1.406087, 1.406~
## $ mean_waveyear <dbl> 1.731754, 1.731754, 1.731754, 1.731~
## $ wh_95prc <dbl> 2.832922, 2.832922, 2.832922, 2.832~
## $ Mean_Monthly_NPP <dbl> 3014.864, 3014.864, 3014.864, 3014.~
## $ Max_Monthly_NPP_Upwelling <dbl> 5837.788, 5837.788, 5837.788, 5837.~
## $ log_den_NERLUE <dbl> 0.000000, 0.000000, 0.000000, 0.000~
## $ log_den_MESFRAAD <dbl> 3.8501476, 4.0352234, 2.0794415, 3.~
## $ log_den_STRPURAD <dbl> 4.0352234, 3.0445224, 6.6214057, 4.~
## $ log_den_PYCHEL <dbl> 0.0000000, 0.0000000, 0.0000000, 0.~
## $ log_den_HALRUF <dbl> 4.0352234, 2.3025851, 3.9318256, 4.~
## $ log_mean_vrm <dbl> 0.0001370786, 0.0001370786, 0.00013~
## $ log_Days_16C <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,~
## $ log_UBR_Mean <dbl> 3.931826, 3.931826, 3.931826, 3.931~
## $ log_UBR_Max <dbl> 5.497168, 5.497168, 5.497168, 5.497~
## $ log_Mean_Monthly_NPP_Upwelling <dbl> 8.085571, 8.085571, 8.085571, 8.085~
## $ log_Min_Monthly_NPP <dbl> 6.893618, 6.893618, 6.893618, 6.893~
```

```
glimpse(dat2)
```

```
## Rows: 686
## Columns: 42
## $ latitude <dbl> 38.5106, 38.5106, 38.5106, 38.5106,~
## $ longitude <dbl> -123.245, -123.245, -123.245, -123.~
## $ site_name <fct> Fort Ross, Fort Ross, Fort Ross, Fo~
## $ year <fct> 2015, 2015, 2015, 2015, 2015, 2015,~
## $ transect <fct> 1, 2, 3, 4, 5, 6, 1, 2, 3, 4, 5, 6,~
## $ zone <fct> OUTER, OUTER, OUTER, INNER, INNER, ~
```

```
## $ Days_10N <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## $ Min_Monthly_Nitrate <dbl> 0.0000000, 0.0000000, 0.0000000, 0.~
## $ Max_Monthly_Nitrate <dbl> 15.50432, 15.50432, 15.50432, 15.50~
## $ Mean_Monthly_Nitrate <dbl> 2.951467, 2.951467, 2.951467, 2.951~
## $ Mean_Monthly_Upwelling_Nitrate <dbl> 7.056086, 7.056086, 7.056086, 7.056~
## $ Max_Monthly_Anomaly_Nitrate <dbl> 0.4776073, 0.4776073, 0.4776073, 0.~
## $ Mean_Monthly_Summer_Nitrate <dbl> 1.290271, 1.290271, 1.290271, 1.290~
## $ Mean_Monthly_Temp <dbl> 12.93553, 12.93553, 12.93553, 12.93~
## $ Mean_Monthly_Summer_Temp <dbl> 14.04160, 14.04160, 14.04160, 14.04~
## $ MHW_Upwelling_Days <int> 33, 33, 33, 33, 33, 33, 0, 0, 0, 0, ~
## $ Min_Monthly_Anomaly_Temp <dbl> -0.05073234, -0.05073234, -0.050732~
## $ Max_Monthly_Anomaly_Upwelling_Temp <dbl> 2.0442495, 2.0442495, 2.0442495, 2.~
## $ Min_Monthly_Temp <dbl> 10.129032, 10.129032, 10.129032, 10~
## $ Mean_Monthly_Upwelling_Temp <dbl> 11.597677, 11.597677, 11.597677, 11~
## $ npgo_mean <dbl> -1.3941667, -1.3941667, -1.3941667, ~
## $ mei_mean <dbl> 1.28333333, 1.28333333, 1.28333333, ~
## $ mean_depth <dbl> -9.040727, -9.040727, -9.040727, -9~
## $ mean_prob_of_rock <dbl> 0.6323734, 0.6323734, 0.6323734, 0.~
## $ mean_slope <dbl> 3.476603, 3.476603, 3.476603, 3.476~
## $ wh_max <dbl> 6.918628, 6.918628, 6.918628, 6.918~
## $ wh_mean <dbl> 1.406087, 1.406087, 1.406087, 1.406~
## $ mean_waveyear <dbl> 1.731754, 1.731754, 1.731754, 1.731~
## $ wh_95prc <dbl> 2.832922, 2.832922, 2.832922, 2.832~
## $ Mean_Monthly_NPP <dbl> 3014.864, 3014.864, 3014.864, 3014.~
## $ Max_Monthly_NPP_Upwelling <dbl> 5837.788, 5837.788, 5837.788, 5837.~
## $ log_den_NERLUE <dbl> 0.000000, 0.000000, 0.000000, 0.000~
## $ log_den_MESFRAAD <dbl> 3.8501476, 4.0352234, 2.0794415, 3.~
## $ log_den_STRPURAD <dbl> 4.0352234, 3.0445224, 6.6214057, 4.~
## $ log_den_PYCHEL <dbl> 0.0000000, 0.0000000, 0.0000000, 0.~
## $ log_den_HALRUF <dbl> 4.0352234, 2.3025851, 3.9318256, 4.~
## $ log_mean_vrm <dbl> 0.0001370786, 0.0001370786, 0.00013~
## $ log_Days_16C <dbl> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ~
## $ log_UBR_Mean <dbl> 3.931826, 3.931826, 3.931826, 3.931~
## $ log_UBR_Max <dbl> 5.497168, 5.497168, 5.497168, 5.497~
## $ log_Mean_Monthly_NPP_Upwelling <dbl> 8.085571, 8.085571, 8.085571, 8.085~
## $ log_Min_Monthly_NPP <dbl> 6.893618, 6.893618, 6.893618, 6.893~
```

```
levels(dat2$year)
```

```
## [1] "2006" "2007" "2008" "2009" "2010" "2011" "2012" "2013" "2014" "2015"
## [11] "2016" "2017" "2018" "2019" "2020" "2021"
```

3. Divide data into train and test

```
# Split data into a training set (75%), and a testing set (25%)
inTraining <- createDataPartition(dat2$log_den_NERLUE, p = 0.75, list = FALSE)
train.gam <- dat2[ inTraining,]
test.gam <- dat2[-inTraining,]
```

4. Run GAM

```
gam1 <- gam(formula = log_den_NERLUE ~
             s(log_den_STRPURAD, k = 5, bs = "cr") +
             s(Max_Monthly_Nitrate, k = 5, bs = "cr") +
             s(wh_max, k = 5, bs = "cr") +
             s(log_UBR_Max, k = 4, bs = "cr") +
             s(site_name, zone, bs = "re") +
             s(year, bs = "re"),
             family = tw(), data = dat2, method = "REML")
```

5. Check GAM

```
gam1$aic
```

```
## [1] 1684.045
```

```
gam1$deviance
```

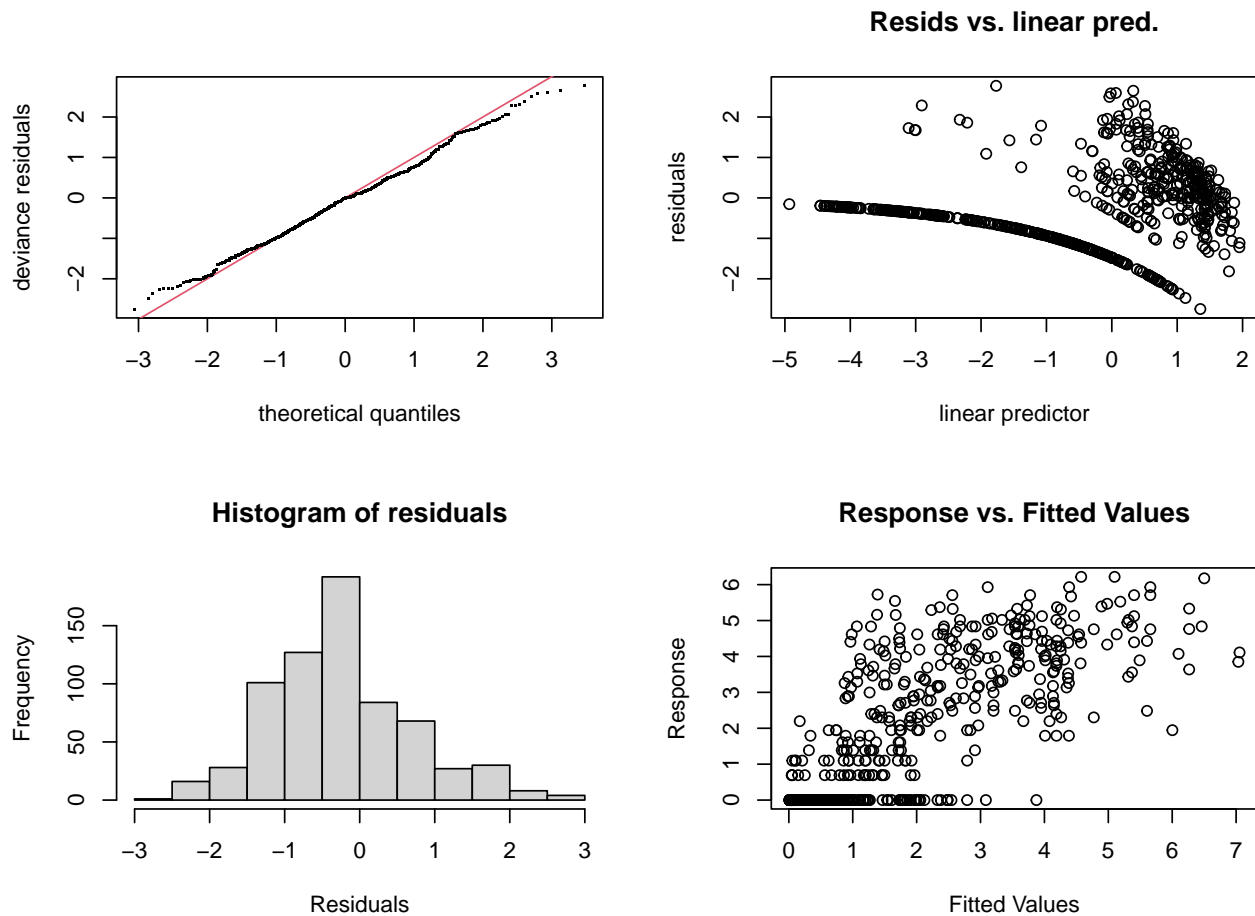
```
## [1] 650.3355
```

```
summary(gam1)
```

```
##
## Family: Tweedie(p=1.085)
## Link function: log
##
## Formula:
## log_den_NERLUE ~ s(log_den_STRPURAD, k = 5, bs = "cr") + s(Max_Monthly_Nitrate,
##      k = 5, bs = "cr") + s(wh_max, k = 5, bs = "cr") + s(log_UBR_Max,
##      k = 4, bs = "cr") + s(site_name, zone, bs = "re") + s(year,
##      bs = "re")
##
## Parametric coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.5254      0.3789  -1.387   0.166
##
## Approximate significance of smooth terms:
##              edf Ref.df      F  p-value
## s(log_den_STRPURAD)    2.358  2.680  8.543 6.17e-05 ***
## s(Max_Monthly_Nitrate) 3.294  3.651 11.159 < 2e-16 ***
## s(wh_max)              3.698  3.918 10.613 < 2e-16 ***
## s(log_UBR_Max)         2.667  2.884  7.611 0.000286 ***
## s(site_name,zone)      15.335 19.000  4.033 2.31e-05 ***
## s(year)                12.784 15.000  9.229 < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) = 0.623  Deviance explained = 64.5%
## -REML = 880.45  Scale est. = 1.3074    n = 686
```



```
gam.check(gam1)
```



```
##
## Method: REML   Optimizer: outer newton
## full convergence after 8 iterations.
## Gradient range [-2.23194e-08,3.732632e-09]
## (score 880.4514 & scale 1.30745).
## Hessian positive definite, eigenvalue range [0.5091827,617.4705].
## Model rank = 52 / 52
##
## Basis dimension (k) checking results. Low p-value (k-index<1) may
## indicate that k is too low, especially if edf is close to k'.
##
##      k'   edf k-index p-value
## s(log_den_STRPURAD)  4.00  2.36   0.80  0.005 **
## s(Max_Monthly_Nitrate) 4.00  3.29   0.59 <2e-16 ***
## s(wh_max)            4.00  3.70   0.59 <2e-16 ***
## s(log_UBR_Max)       3.00  2.67   0.62 <2e-16 ***
## s(site_name,zone)    20.00 15.33   NA    NA
## s(year)              16.00 12.78   NA    NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
# visualize responses
par(mfrow = c(3, 3), mar = c(2, 4, 3, 1))
visreg(gam1)
dev.off()
```

```
## null device
##          1
```

6. Predict to compare to observed

```
testdata <- dat2 %>%
  dplyr::select("log_den_STRPURAD",
               "log_mean_vrm",
               "log_UBR_Max",
               "Max_Monthly_Nitrate",
               "wh_max",
               "log_den_NERLUE",
               "site_name", "zone", "year")

head(testdata)
```

```
##   log_den_STRPURAD log_mean_vrm log_UBR_Max Max_Monthly_Nitrate wh_max
## 1      4.035223 0.0001370786    5.497168      15.50432 6.918628
## 2      3.044522 0.0001370786    5.497168      15.50432 6.918628
## 3      6.621406 0.0001370786    5.497168      15.50432 6.918628
## 4      4.072309 0.0001370786    5.497168      15.50432 6.918628
## 5      3.828641 0.0001370786    5.497168      15.50432 6.918628
## 6      6.216606 0.0001370786    5.497168      15.50432 6.918628
##   log_den_NERLUE site_name zone year
## 1              0 Fort Ross OUTER 2015
## 2              0 Fort Ross OUTER 2015
## 3              0 Fort Ross OUTER 2015
## 4              0 Fort Ross INNER 2015
## 5              0 Fort Ross INNER 2015
## 6              0 Fort Ross INNER 2015
```

```
# fit the data
fits <- predict.gam(gam1, newdata = testdata, type = 'response', se.fit = T)
```

```
## predict average kelp per year --
predicts.year <- testdata %>%
  data.frame(fits) %>%
  group_by(year) %>% #only change here
  summarise(response=mean(fit, na.rm = T), se.fit = mean(se.fit, na.rm = T))%>%
  ungroup()
```

```
ggmod.year <- ggplot(aes(x = year, y = response, fill = year), data = predicts.year) +
  ylab(" ") +
```

```

xlab('survey_year')+
scale_fill_viridis(discrete = T) +
geom_bar(stat = "identity")+
geom_errorbar(aes(ymin = response - se.fit, ymax = response + se.fit),width = 0.5) +
theme_classic() +
theme(axis.text.x = element_text(angle = 45, h = 1))

```

ggmod.year

