SURE Project

August 20, 2022

Objective

Compare spatial predictions of kelp to "in situ" survey data. Compare each year and location.

Extraction

Extract the predicted *log* kelps density of every year (2004 - 2021) for each site in the North Coast.

```
# set a directory
w.dir <- here()
d.dir <- here('data')
r.dir <- here('spatial_data/sp_predictions_5.1.1_V2')
# rock.dir <- here('spatial_data/sp_predictions_5.1.1_V2_rock')

# read and transform the observed data to the log scale
df <- read.csv(paste(d.dir,
                     'RCCA_kelp_inverts_NC_depth-zones_wave_clim_temp_nit_subs_orbvel_npp.csv',
                     sep = '/')) %>%
  dplyr::select(site_name, year, transect, zone, latitude, longitude, den_NERLUE) %>%
  mutate_at(vars(year, transect, zone, site_name), list(as.factor)) %>%
  mutate(log_den_NERLUE = log(den_NERLUE))
head(df)
```

```
##   site_name year transect  zone latitude longitude den_NERLUE log_den_NERLUE
## 1    Caspar 2018        1 INNER 39.36173  -123.822          0           -Inf
## 2    Caspar 2018        2 INNER 39.36173  -123.822          0           -Inf
## 3    Caspar 2018        3 INNER 39.36173  -123.822          0           -Inf
## 4    Caspar 2018        4 OUTER 39.36173  -123.822          0           -Inf
## 5    Caspar 2018        5 OUTER 39.36173  -123.822          0           -Inf
## 6    Caspar 2018        6 OUTER 39.36173  -123.822          0           -Inf
```

Note that log(0) returns -Inf.

```
filter(df, den_NERLUE == 0) %>% count() # 719 0's
```

```
##     n
## 1 719
```

How to deal with log(0)?

```
df$log_den_NERLUE <- replace(df$log_den_NERLUE, df$log_den_NERLUE == -Inf, 0)
head(df)
```

```
##   site_name year transect  zone latitude longitude den_NERLUE log_den_NERLUE
## 1    Caspar 2018        1 INNER 39.36173  -123.822          0              0
## 2    Caspar 2018        2 INNER 39.36173  -123.822          0              0
## 3    Caspar 2018        3 INNER 39.36173  -123.822          0              0
## 4    Caspar 2018        4 OUTER 39.36173  -123.822          0              0
## 5    Caspar 2018        5 OUTER 39.36173  -123.822          0              0
## 6    Caspar 2018        6 OUTER 39.36173  -123.822          0              0
```

Calculate the mean and standard error of kelps density of every year for each site by zone (INNER/OUTER).

```
obs <- df %>%
  group_by(site_name, year, zone) %>%
  summarise_at(vars(log_den_NERLUE), list(mean = mean, se = std.error), na.rm = TRUE) %>%
  pivot_wider(names_from = zone, values_from = c(mean, se))
head(obs)
```

```
## # A tibble: 6 x 6
## # Groups:   site_name, year [6]
##   site_name year  mean_INNER mean_OUTER se_INNER se_OUTER
##   <fct>     <fct>      <dbl>      <dbl>    <dbl>    <dbl>
## 1 Caspar    2008       4.38        3.03   0.150     0.996
## 2 Caspar    2010       4.37        4.17   0.0664    0.586
## 3 Caspar    2014       0.799       0      0.799     0
## 4 Caspar    2015       0           0      0         0
## 5 Caspar    2016       0           0      0         0
## 6 Caspar    2017       0           0      0         0
```

Extract the predicted *log* kelps density of every year for each site.

```
# read the .csv file
site <- read.csv(paste(d.dir,
                       'RCCA_North_Coast_sites.csv',
                       sep = '/'))
# convert from .csv to .shp
site_shp <- st_as_sf(site, coords = c('longitude', 'latitude'), crs = 'EPSG:4326')
# write the file
st_write(site_shp, paste0(d.dir, '/RCCA_North_Coast_sites.shp'), append = FALSE)
```

```
## Deleting layer 'RCCA_North_Coast_sites' using driver 'ESRI Shapefile'
## Writing layer 'RCCA_North_Coast_sites' to data source
##   '/Users/chuntingzheng/Desktop/Git_Repositories/Chunting_Spatial_Analyses/data/RCCA_North_Coast_site
## Writing 25 features with 5 fields and geometry type Point.
```

```
# declaring an empty data frame
pred <- data.frame(site_name = character(),
                   year = numeric(),
                   fit = numeric())
```

```
for (i in c(2006:2021)) {
  rast <- rast(paste0(r.dir, paste0('/', i, '_Nereo_preds_NC_V4_5.1.1_V2.tif')))
  ext <- terra::extract(rast, vect(site_shp$geometry)) %>%
    mutate(site_name = site$site_name, year = as.factor(i), .before = fit) %>%
    dplyr::select(-ID)
  pred <- rbind(pred, ext)
}

head(pred)
```

```
##        site_name year       fit
## 1         Caspar 2006 0.5090384
## 2   Caspar North 2006 0.5003366
## 3     Dark Gulch 2006 0.5309656
## 4 Flat Iron Rock 2006 0.7382968
## 5      Fort Ross 2006       NaN
## 6    Frolic Cove 2006 0.8228083
```

```
# sites and years have predicted values higher than 6.6 (log of density)
filter(pred, fit >= 6.6)
```

```
##                 site_name year        fit
## 1    Point Arena MPA (M2) 2007   8.662991
## 2         Point Arena Ref 2007  21.406689
## 3             Timber Cove 2007  23.488674
## 4              Dark Gulch 2008  19.940689
## 5          Flat Iron Rock 2008  22.692287
## 6             Frolic Cove 2008  11.673522
## 7             Glass Beach 2008  18.386805
## 8      MacKerricher North 2008  22.953793
## 9     Mendocino Headlands 2008  33.649105
## 10               Monument 2008 211.603195
## 11           Pebble Beach 2008  17.207937
## 12 Point Arena Lighthouse 2008  51.701321
## 13   Point Arena MPA (M2) 2008 377.264008
## 14        Point Arena Ref 2008 365.663879
## 15       Portuguese Beach 2008 102.522873
## 16          Pyramid Point 2008 342.526245
## 17          Russian Gulch 2008  22.330360
## 18      Stillwater Sonoma 2008  22.428894
## 19              Stornetta 2008  12.890643
## 20            Timber Cove 2008 409.307465
## 21              Van Damme 2008   9.219850
## 22             Dark Gulch 2009  23.877867
## 23            Frolic Cove 2009  98.134544
## 24     MacKerricher North 2009  11.300843
## 25               Monument 2009 288.878967
## 26 Point Arena Lighthouse 2009  58.657776
## 27   Point Arena MPA (M2) 2009 290.192169
## 28        Point Arena Ref 2009  27.217886
## 29          Pyramid Point 2009  19.214815
## 30          Russian Gulch 2009  10.897983
```

```
## 31              Stornetta 2009  19.797838
## 32           Timber Cove 2009   8.495423
## 33          Pebble Beach 2012   7.714611
## 34       Point Arena Ref 2012  19.095858
## 35           Timber Cove 2012  19.386978
## 36         Pyramid Point 2013  14.741710
## 37      Portuguese Beach 2021   7.111959
```

Comparison

Compare the predicted data to observed data.

```
dim(obs)
```

```
## [1] 193   6
```

```
dim(pred)
```

```
## [1] 400   3
```

```
kelp_data <- left_join(pred, obs, by = c('site_name', 'year')) %>%
  group_by(site_name) %>%
  arrange(year, .by_group = TRUE) %>%
  relocate(fit, .after = last_col())
head(kelp_data)
```

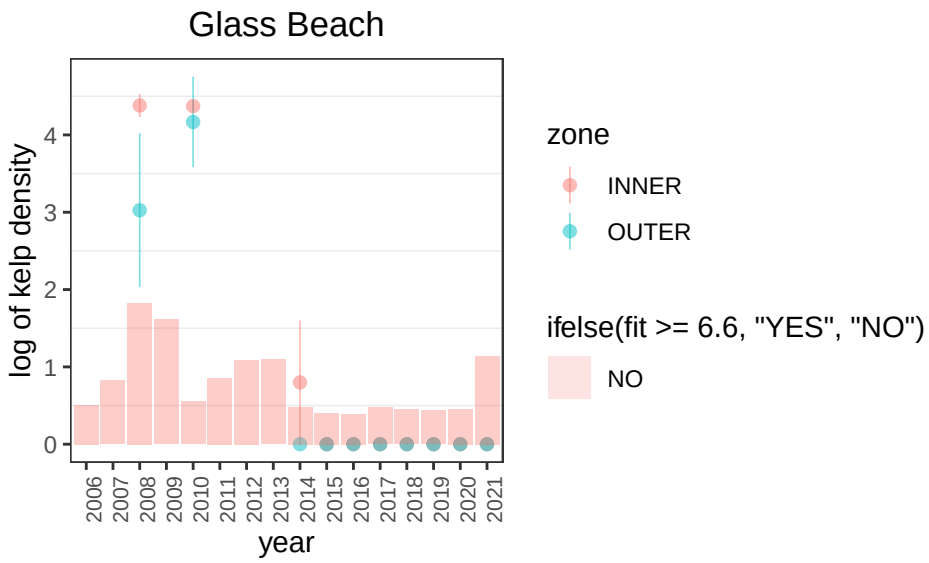
```
## # A tibble: 6 x 7
## # Groups:   site_name [1]
##   site_name year  mean_INNER mean_OUTER se_INNER se_OUTER   fit
##   <chr>     <fct>      <dbl>      <dbl>    <dbl>    <dbl> <dbl>
## 1 Caspar    2006       NA         NA     NA        NA     0.509
## 2 Caspar    2007       NA         NA     NA        NA     0.827
## 3 Caspar    2008        4.38       3.03   0.150     0.996 1.83
## 4 Caspar    2009       NA         NA     NA        NA     1.62
## 5 Caspar    2010        4.37       4.17   0.0664    0.586 0.554
## 6 Caspar    2011       NA         NA     NA        NA     0.857
```

Plotting

Plot log of kelps density vs year for each site.

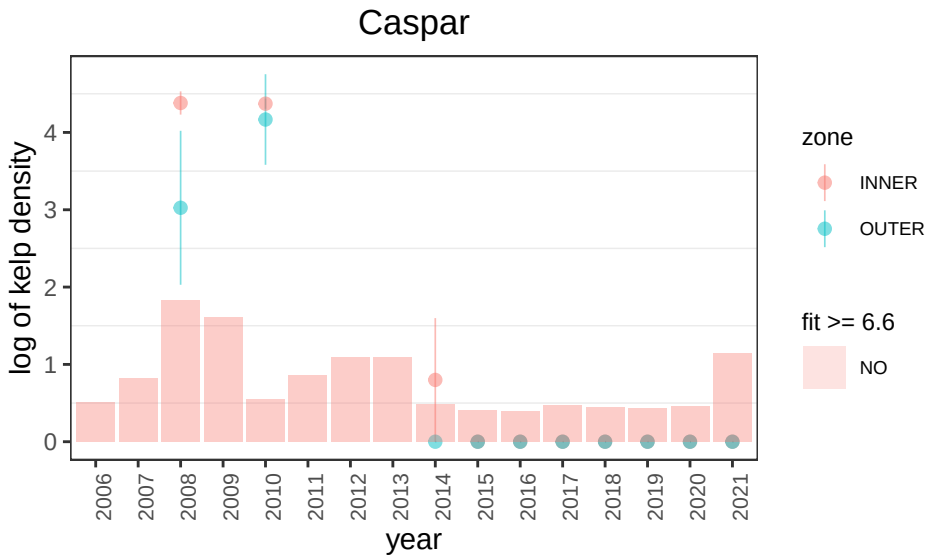
```
# kelp_data %>%
#   pivot_longer(
#     -c('site_name', 'year', 'fit'),
#     names_to = c('.value', 'zone'),
#     names_sep = '_'
#     ) %>%
#   filter(site_name == 'Caspar') %>%
#   ggplot(aes(x = year, y = mean, fill = zone)) +
#   geom_bar(position = 'dodge', stat = 'identity')
```

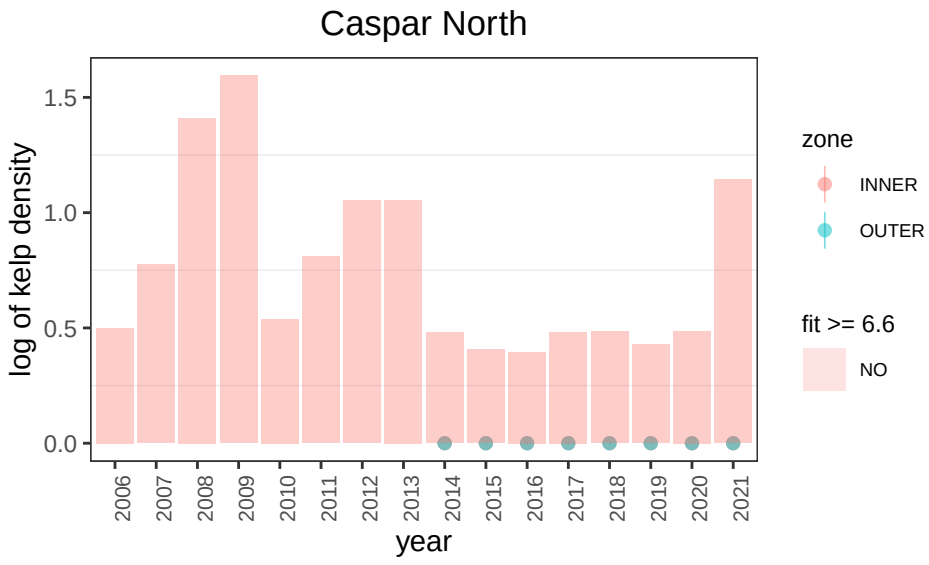
```
sites <- unique(kelp_data$site_name)
kelp_longer <- kelp_data %>%
    pivot_longer(
      -c('site_name', 'year', 'fit'),
      names_to = c('.value', 'zone'),
      names_sep = '_'
      )

kelp_longer %>%
    filter(site_name == 'Caspar') %>%
    ggplot() +
    geom_pointrange(aes(
      x = year, y = mean, group = zone, color = zone,
      ymin = mean - se, ymax = mean + se
      ), alpha = 0.5, size = 0.3) +
    geom_bar(aes(x = year, y = fit, fill = ifelse(fit >= 6.6, 'YES', 'NO')),
             stat = 'identity', position = 'dodge', alpha = 0.2) +
    theme_bw() +
    theme(axis.text.x = element_text(angle = 90, size = 8),
          plot.title = element_text(hjust = 0.5),
          panel.grid.major = element_blank()) +
    labs(y = 'log of kelp density', title = 'Glass Beach')
```

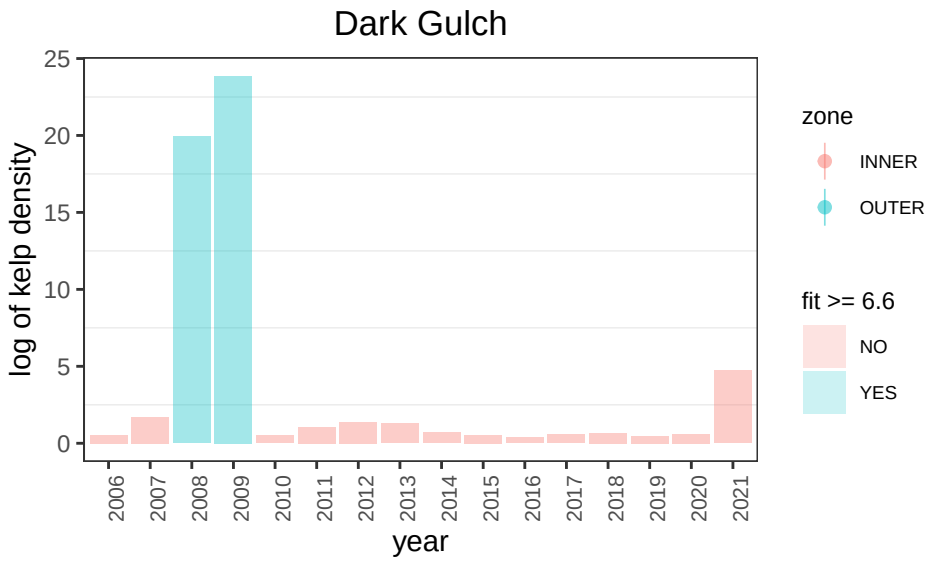


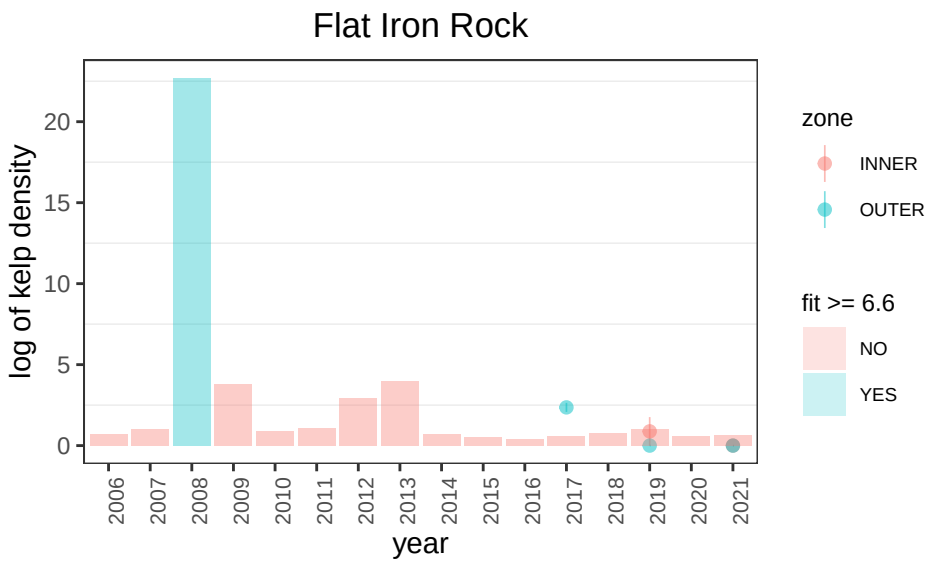

```
for (i in sites) {
  plot <- kelp_longer %>%
    filter(site_name == i) %>%
    ggplot() +
    geom_pointrange(aes(
      x = year, y = mean, group = zone, color = zone,
      ymin = mean - se, ymax = mean + se
      ), alpha = 0.5, size = 0.3) +
    geom_bar(aes(x = year, y = fit,
                 fill = ifelse(!is.na(fit) & fit >= 6.6, 'YES', 'NO')),
             stat = 'identity', position = 'dodge', alpha = 0.2) +
```

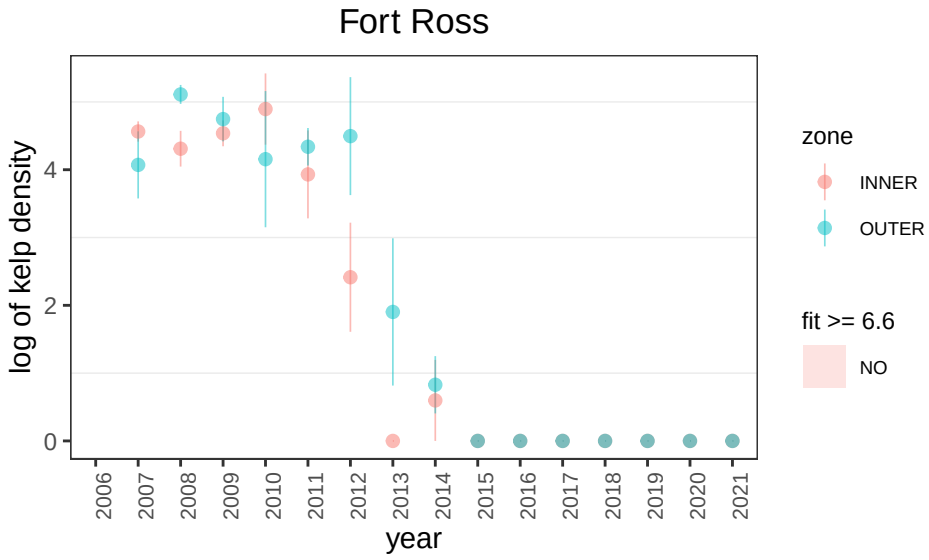
```
    theme_bw() +
    theme(axis.text.x = element_text(angle = 90, size = 8),
          plot.title = element_text(hjust = 0.5),
          panel.grid.major = element_blank(),
          legend.title = element_text(size = 9),
          legend.text = element_text(size = 7)) +
    labs(y = 'log of kelp density', title = i, fill = 'fit >= 6.6')
  print(plot)
}
```

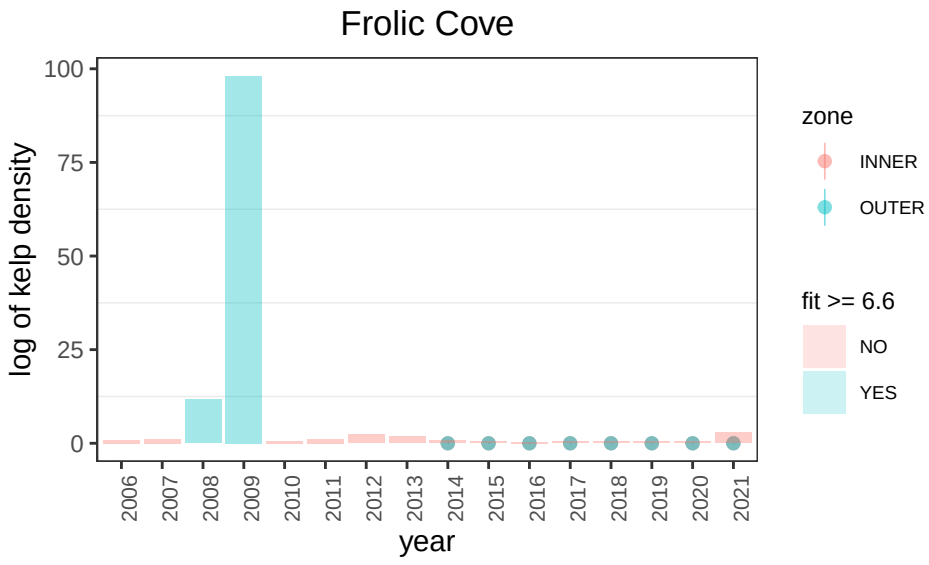


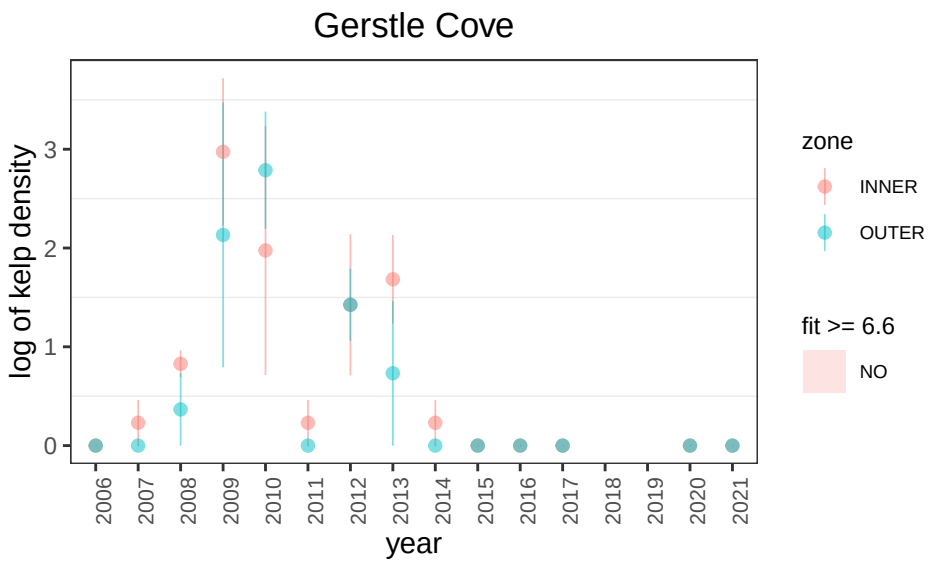


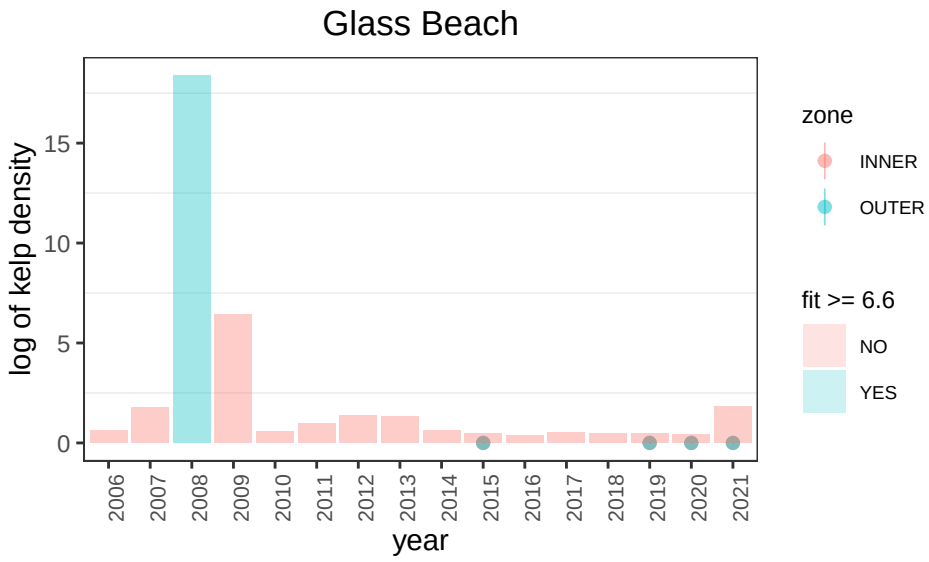

Dark Gulch
log of kelp density
25
20
15
10
5
0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

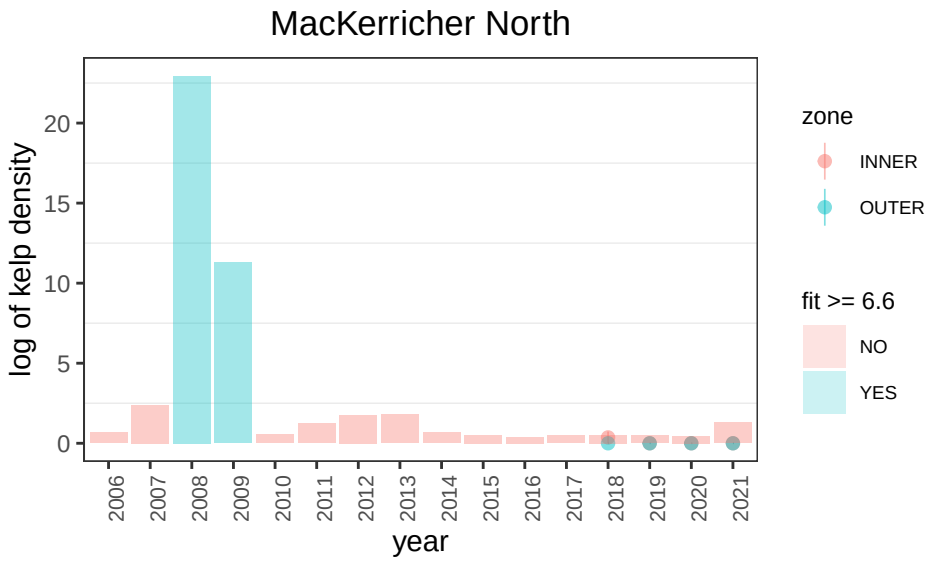

Flat Iron Rock
log of kelp density
20
15
10
5
0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

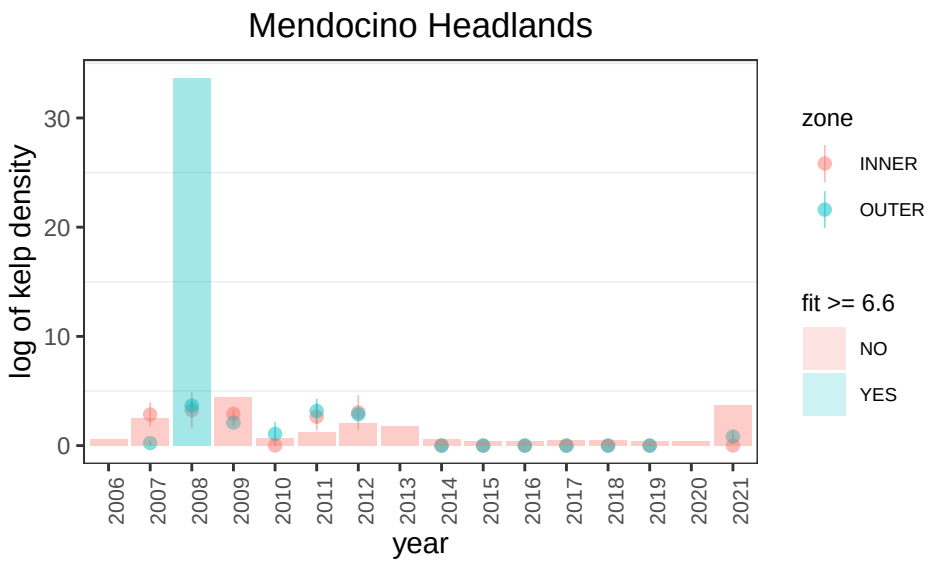

Fort Ross
log of kelp density
4
2
0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO

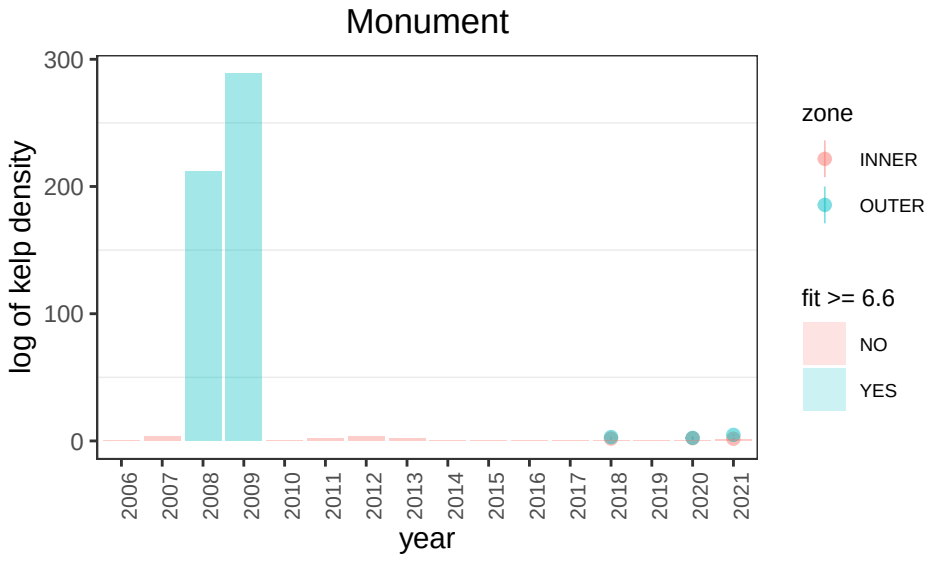

Frolic Cove
log of kelp density
100
75
50
25
0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

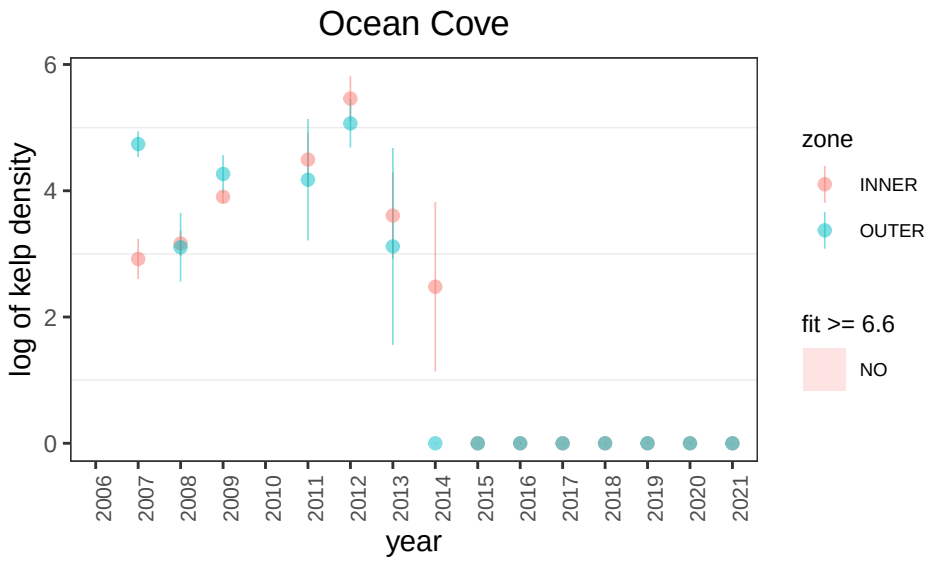

Gerstle Cove
log of kelp density
3
2
1
0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO

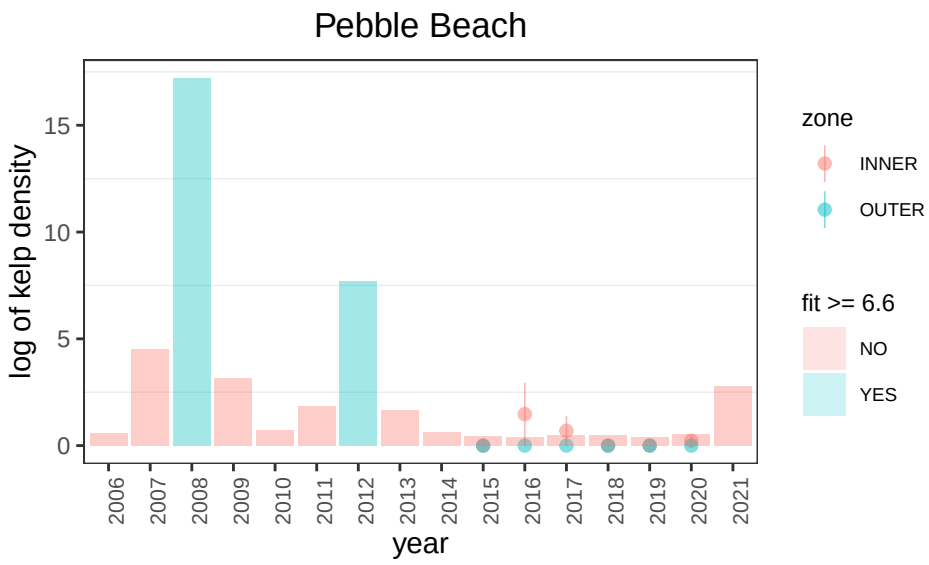

Glass Beach
log of kelp density
15
10
5
0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

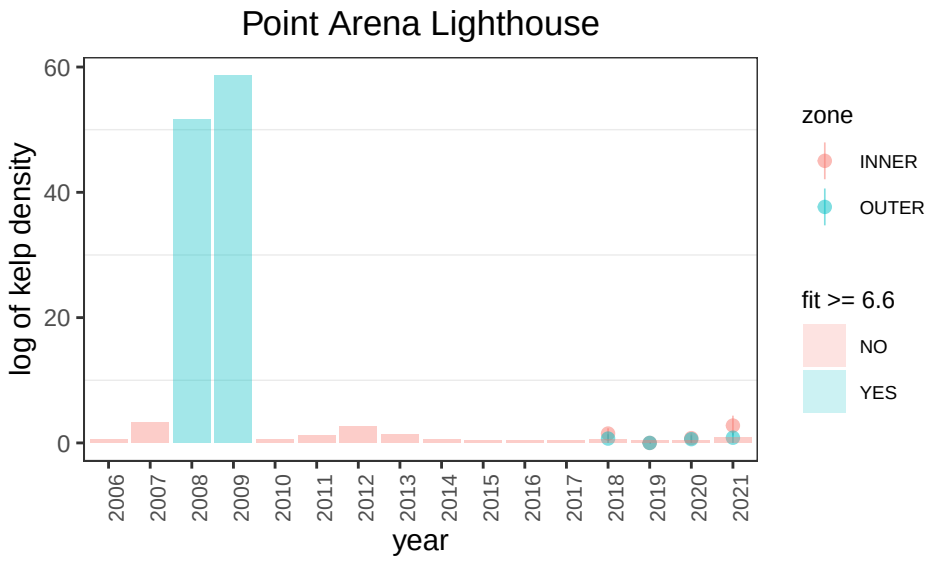

MacKerricher North
log of kelp density
0
5
10
15
20
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

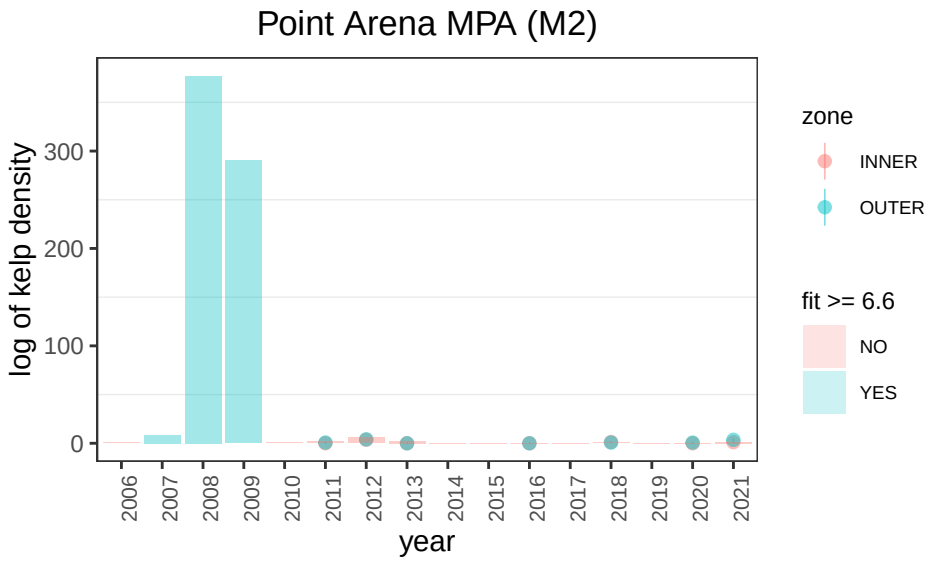

Mendocino Headlands
log of kelp density
0
10
20
30
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

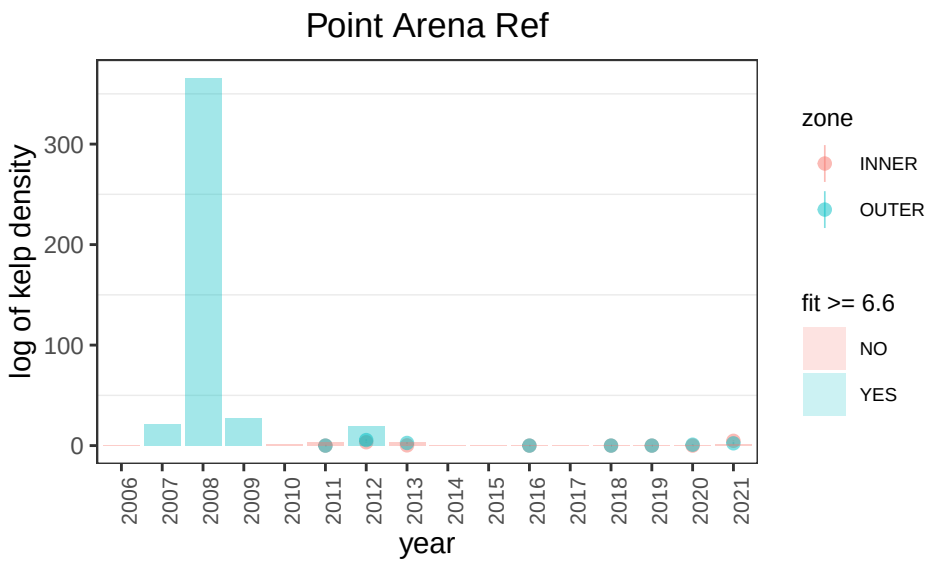

Monument
log of kelp density
0
100
200
300
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

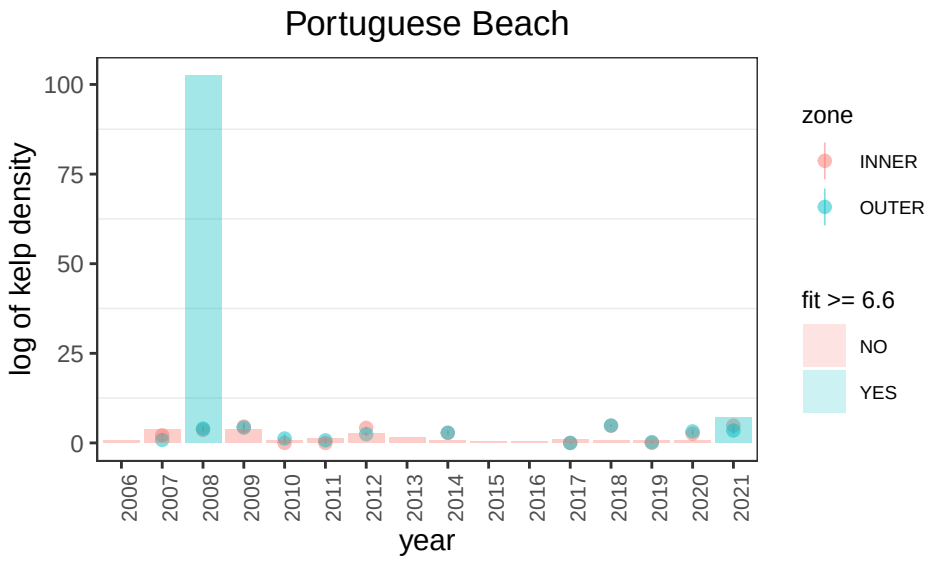

Ocean Cove
log of kelp density
6
4
2
0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO

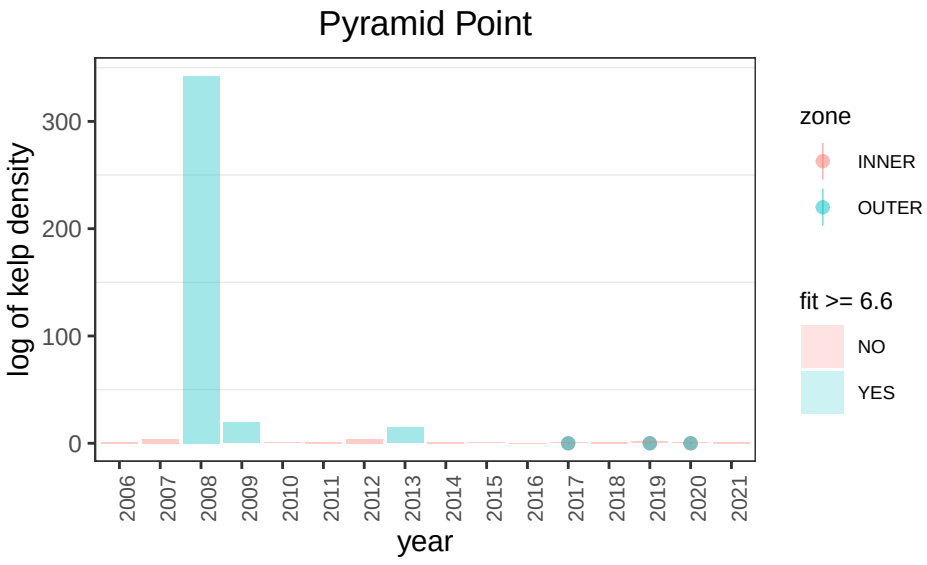

Pebble Beach
log of kelp density
15
10
5
0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

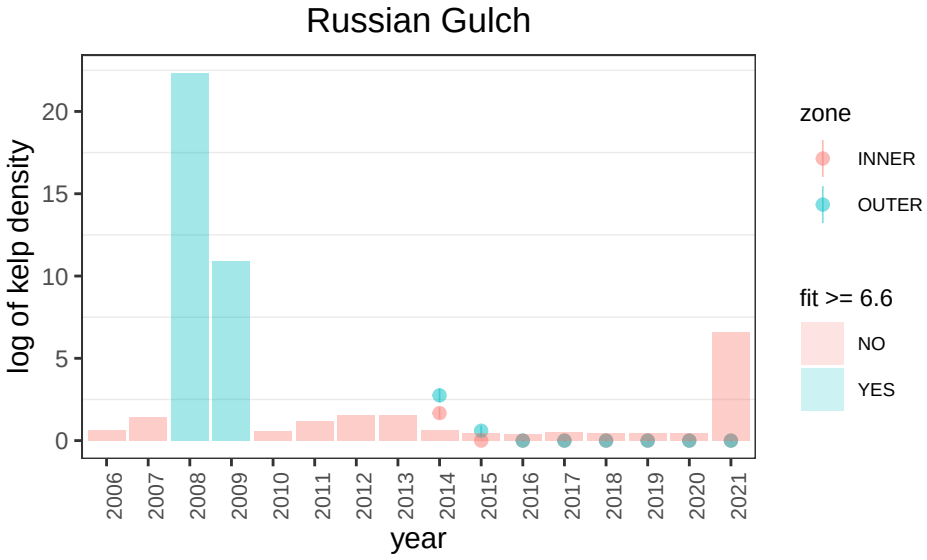

Point Arena Lighthouse
log of kelp density
60
40
20
0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

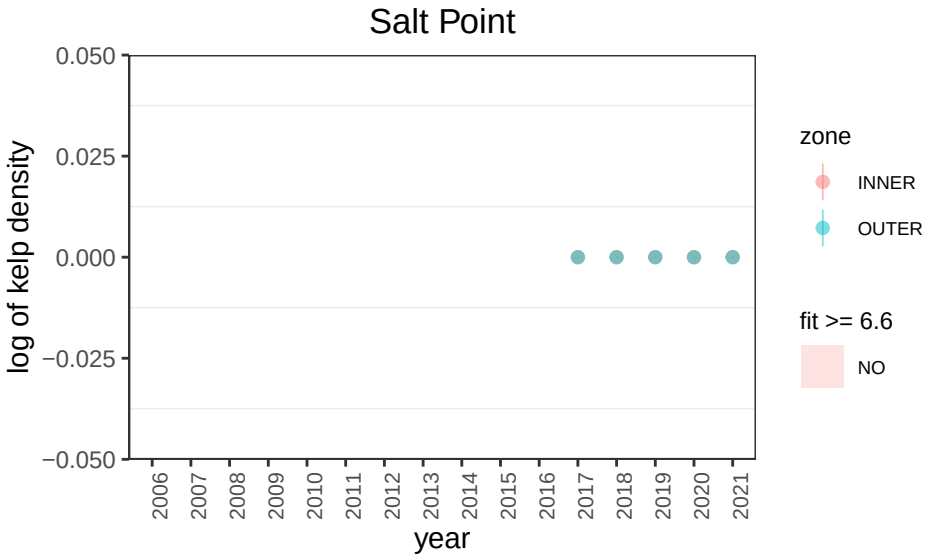

Point Arena MPA (M2)
log of kelp density
0
100
200
300
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

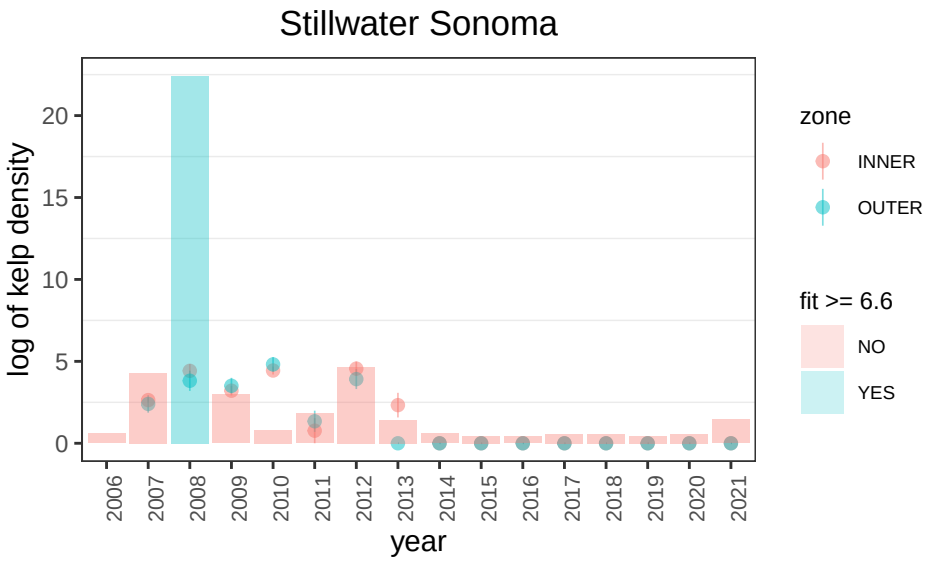

Point Arena Ref
log of kelp density
0
100
200
300
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

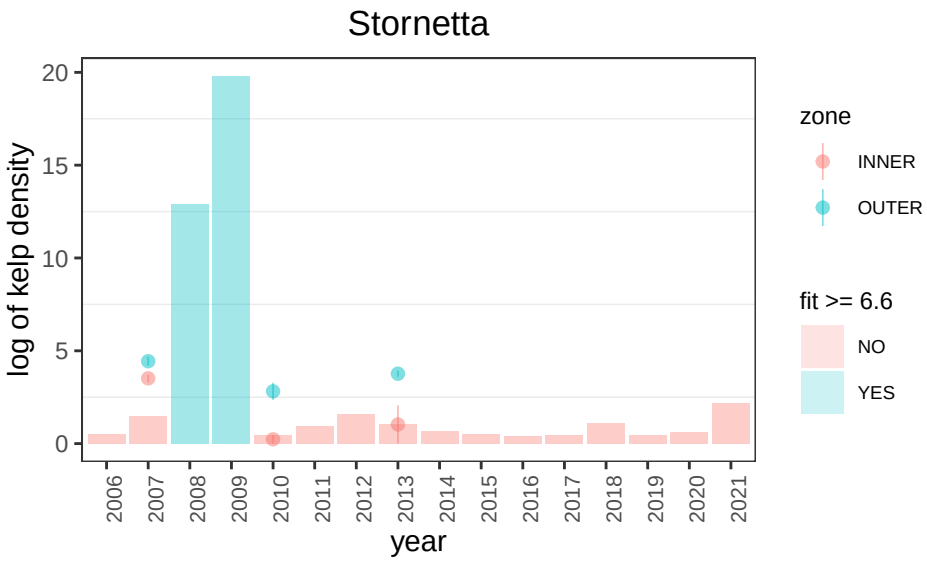

Portuguese Beach
log of kelp density
0
25
50
75
100
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

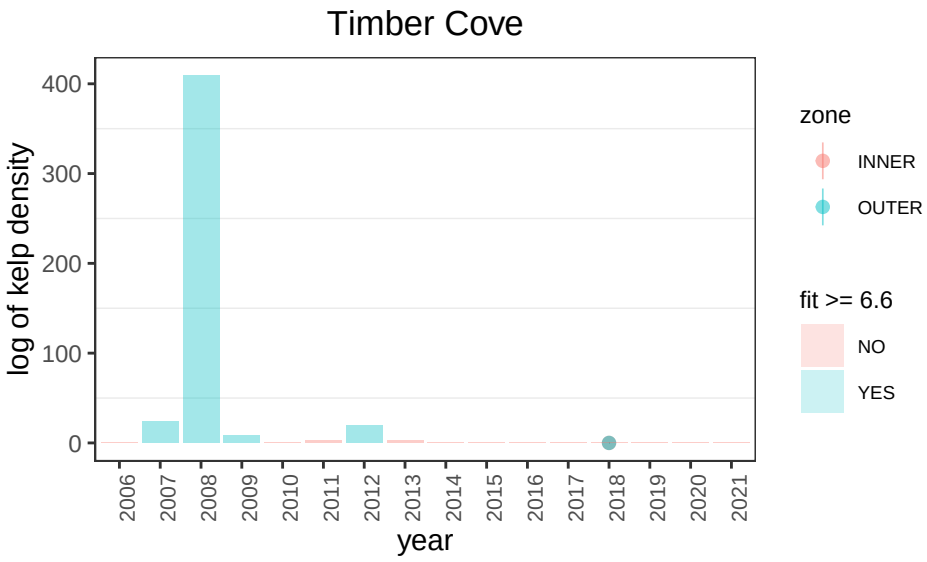

Pyramid Point
log of kelp density
300
200
100
0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

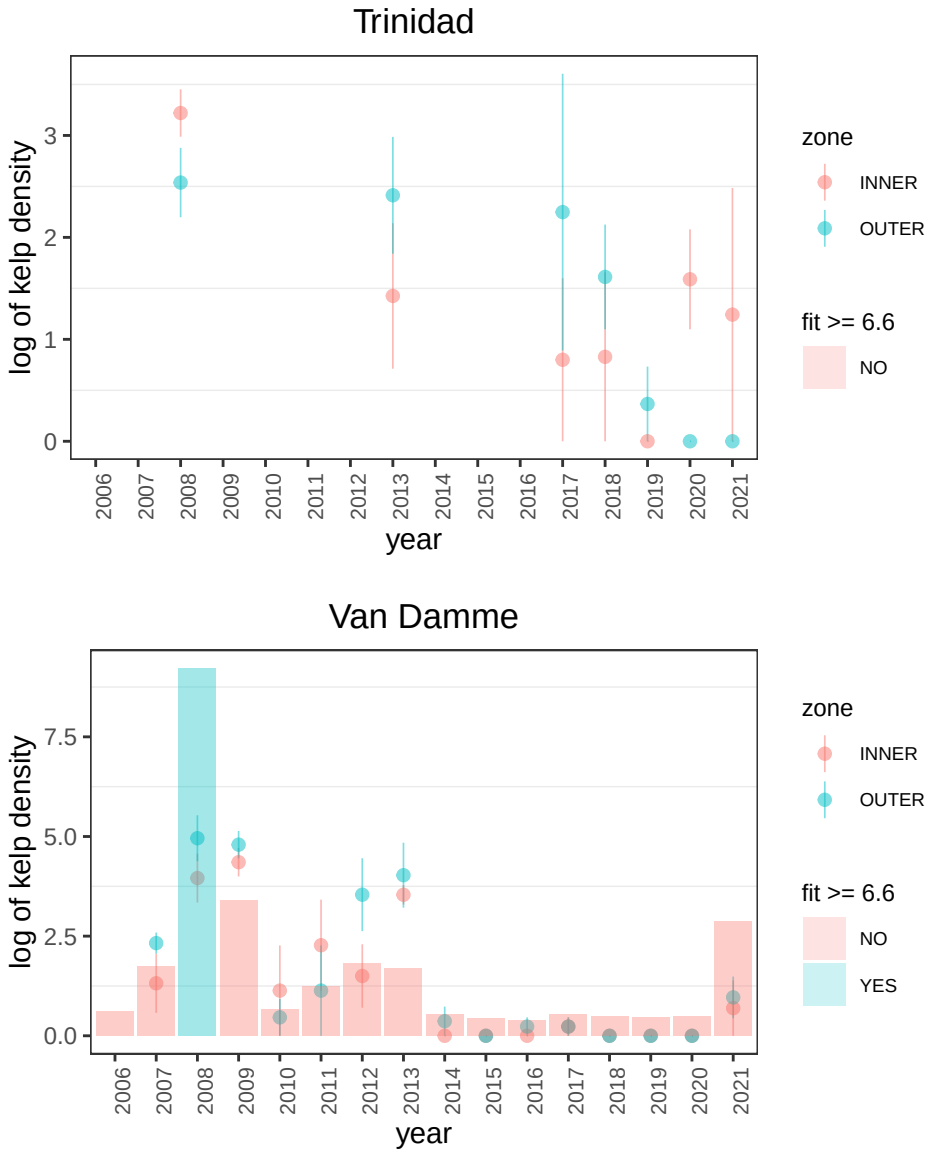

Russian Gulch
log of kelp density
20
15
10
5
0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES


Salt Point
log of kelp density
0.050
0.025
0.000
−0.025
−0.050
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO


Stillwater Sonoma
log of kelp density
0
5
10
15
20
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

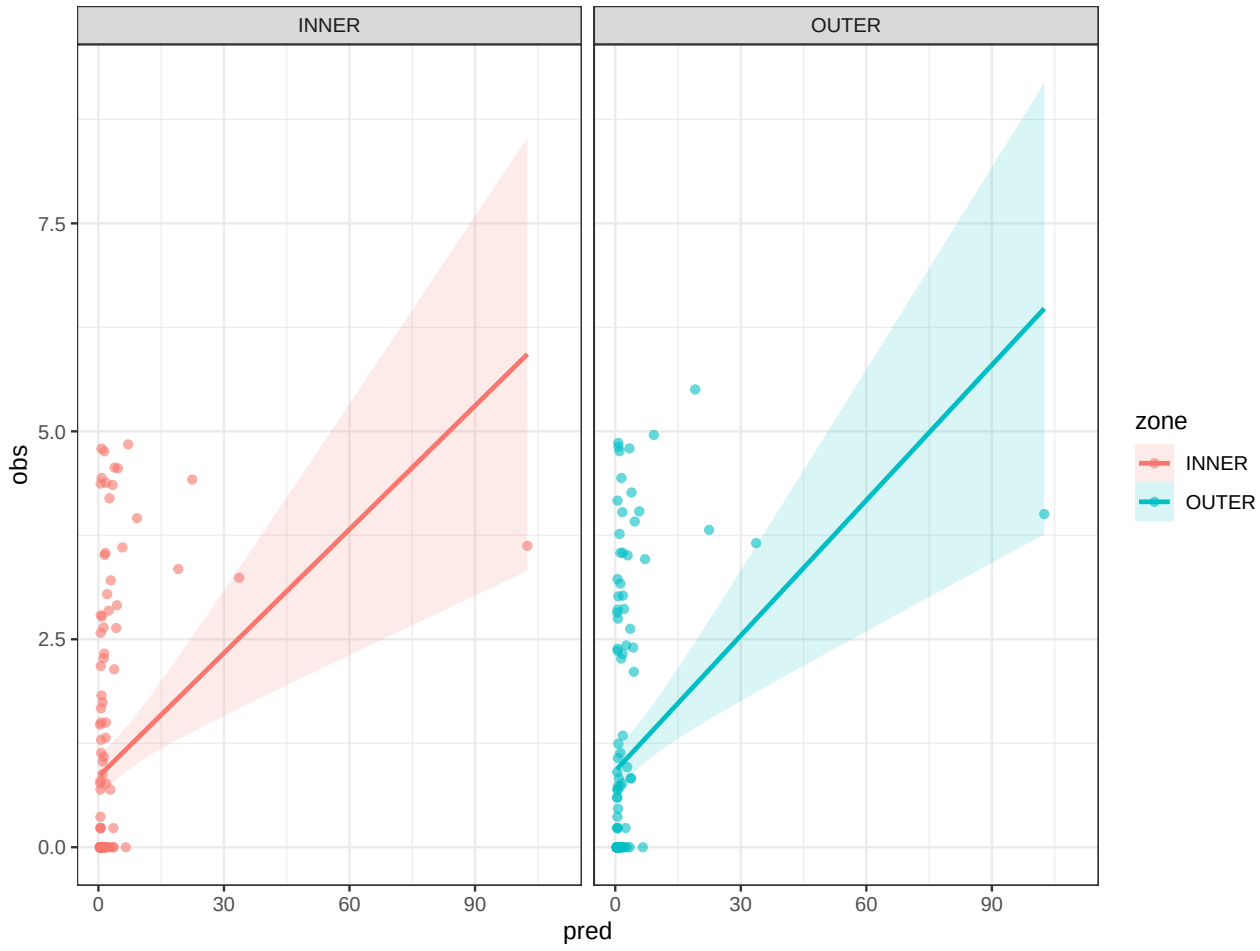

Stornetta
log of kelp density
0
5
10
15
20
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES


Timber Cove
log of kelp density
0
100
200
300
400
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES



Plot obs. vs pred.

```
kelp_longer %>%
  ggplot(aes(x = fit, y = mean, color = zone)) +
  geom_point(alpha = 0.6) +
  geom_smooth(method = 'lm', alpha = 0.15, aes(fill = zone)) +
  xlim(NA, 110) +
  labs(x = 'pred', y = 'obs') +
  facet_wrap(~zone, ncol = 2) +
  theme_bw()
```


INNER
OUTER
obs
pred
7.5
5.0
2.5
0.0
0
30
60
90
zone
INNER
OUTER