# SURE Project

September 24, 2022

## Objective

Compare spatial predictions of kelp to "in situ" survey data. Compare each year and location for 150, 300, 600, 900 resolutions.

## 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 <- '/Volumes/Chunting HD/Git_Repositories/Chunting_Spatial_Analyses/spatial_data'

r1.dir <- paste(r.dir, 'sp_predictions_300m', sep ='/')
r2.dir <- paste(r.dir, 'sp_predictions_1500m', sep ='/')
r3.dir <- paste(r.dir, 'sp_predictions_600m', sep ='/')
r4.dir <- paste(r.dir, 'sp_predictions_900m', sep ='/')
r5.dir <- paste(r.dir, 'sp_predictions_150m', sep ='/')
r6.dir <- paste(r.dir, 'sp_predictions_120m', sep ='/')

# 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. How to deal with log(0)?

```
df$log_den_NERLUE <- replace(df$log_den_NERLUE, df$log_den_NERLUE == -Inf, 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 at different resolutions.

```
# kelp density predictions at different resolutions ----

# # 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')
#
# # declaring an empty data frame
# pred <- data.frame(site_name = character(),
#                    year = numeric(),
#                    fit = numeric())
#
# for (i in c(2006:2021)) {
#   rast <- rast(paste0(r6.dir, paste0('/', i, '_Log_Nereo_NC.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)
#
# # write to cvs
# merge_df <- left_join(pred,
#                       site %>% dplyr::select(c(site_name, longitude, latitude)),
#                       by = 'site_name')
#
# write.csv(merge_df, file.path(d.dir, 'NC_kelp_density_predictions_120m.csv'), row.names = FALSE)
```

## Comparison

```
# kelp density predictions at 300m resolution
pred_300m <- read.csv(paste(d.dir, 'NC_kelp_density_predictions_300m.csv', sep ='/')) %>%
  mutate_at(vars(year, site_name), list(as.factor))

kelp_data_300m <- left_join(pred_300m, obs, by = c('site_name', 'year')) %>%
  group_by(site_name) %>%
  arrange(year, .by_group = TRUE) %>%
  relocate(fit, .after = last_col())
head(kelp_data_300m)
```

```
## # A tibble: 6 x 9
## # Groups:   site_name [1]
##   site_name year  longitude latitude mean_INNER mean_OUTER se_IN~1 se_OU~2   fit
##   <fct>     <fct>     <dbl>    <dbl>      <dbl>      <dbl>   <dbl>   <dbl> <dbl>
## 1 Caspar    2006      -124.     39.4      NA         NA     NA       NA     0.115
## 2 Caspar    2007      -124.     39.4      NA         NA     NA       NA     2.16
## 3 Caspar    2008      -124.     39.4       4.38       3.03  0.150    0.996 3.29
## 4 Caspar    2009      -124.     39.4      NA         NA     NA       NA     7.83
## 5 Caspar    2010      -124.     39.4       4.37       4.17  0.0664   0.586 0.563
## 6 Caspar    2011      -124.     39.4      NA         NA     NA       NA     2.14
## # ... with abbreviated variable names 1: se_INNER, 2: se_OUTER
```

```
# kelp density predictions at 600m resolution
pred_600m <- read.csv(paste(d.dir, 'NC_kelp_density_predictions_600m.csv', sep ='/')) %>%
  mutate_at(vars(year, site_name), list(as.factor))

kelp_data_600m <- left_join(pred_600m, obs, by = c('site_name', 'year')) %>%
  group_by(site_name) %>%
  arrange(year, .by_group = TRUE) %>%
  relocate(fit, .after = last_col())
head(kelp_data_600m)
```

```
## # A tibble: 6 x 9
## # Groups:   site_name [1]
##   site_name year  longitude latitude mean_INNER mean_OU~1 se_IN~2 se_OU~3    fit
##   <fct>     <fct>     <dbl>    <dbl>      <dbl>     <dbl>   <dbl>   <dbl>  <dbl>
## 1 Caspar    2006      -124.     39.4      NA         NA     NA       NA     0.0858
## 2 Caspar    2007      -124.     39.4      NA         NA     NA       NA     1.12
## 3 Caspar    2008      -124.     39.4       4.38       3.03  0.150    0.996 4.00
## 4 Caspar    2009      -124.     39.4      NA         NA     NA       NA     7.98
## 5 Caspar    2010      -124.     39.4       4.37       4.17  0.0664   0.586 0.229
## 6 Caspar    2011      -124.     39.4      NA         NA     NA       NA     0.999
## # ... with abbreviated variable names 1: mean_OUTER, 2: se_INNER, 3: se_OUTER
```

```
# kelp density predictions at 900m resolution
pred_900m <- read.csv(paste(d.dir, 'NC_kelp_density_predictions_900m.csv', sep ='/')) %>%
  mutate_at(vars(year, site_name), list(as.factor))

kelp_data_900m <- left_join(pred_900m, obs, by = c('site_name', 'year')) %>%
  group_by(site_name) %>%
  arrange(year, .by_group = TRUE) %>%
```

```
  relocate(fit, .after = last_col())
head(kelp_data_900m)
```

```
## # A tibble: 6 x 9
## # Groups:   site_name [1]
##   site_name year  longitude latitude mean_INNER mean_OU~1 se_IN~2 se_OU~3    fit
##   <fct>     <fct>     <dbl>    <dbl>      <dbl>     <dbl>   <dbl>   <dbl>  <dbl>
## 1 Caspar    2006      -124.     39.4      NA        NA    NA       NA     0.0758
## 2 Caspar    2007      -124.     39.4      NA        NA    NA       NA     1.50
## 3 Caspar    2008      -124.     39.4       4.38      3.03  0.150    0.996 3.58
## 4 Caspar    2009      -124.     39.4      NA        NA    NA       NA     5.57
## 5 Caspar    2010      -124.     39.4       4.37      4.17  0.0664   0.586 0.339
## 6 Caspar    2011      -124.     39.4      NA        NA    NA       NA     1.44
## # ... with abbreviated variable names 1: mean_OUTER, 2: se_INNER, 3: se_OUTER
```

```
# kelp density predictions at 1500m resolution
pred_1500m <- read.csv(paste(d.dir, 'NC_kelp_density_predictions_1500m.csv', sep ='/')) %>%
  mutate_at(vars(year, site_name), list(as.factor))

kelp_data_1500m <- left_join(pred_1500m, obs, by = c('site_name', 'year')) %>%
  group_by(site_name) %>%
  arrange(year, .by_group = TRUE) %>%
  relocate(fit, .after = last_col())
head(kelp_data_1500m)
```

```
## # A tibble: 6 x 9
## # Groups:   site_name [1]
##   site_name year  longitude latitude mean_INNER mean_OU~1 se_IN~2 se_OU~3    fit
##   <fct>     <fct>     <dbl>    <dbl>      <dbl>     <dbl>   <dbl>   <dbl>  <dbl>
## 1 Caspar    2006      -124.     39.4      NA        NA    NA       NA     0.120
## 2 Caspar    2007      -124.     39.4      NA        NA    NA       NA     1.27
## 3 Caspar    2008      -124.     39.4       4.38      3.03  0.150    0.996  6.19
## 4 Caspar    2009      -124.     39.4      NA        NA    NA       NA    11.2
## 5 Caspar    2010      -124.     39.4       4.37      4.17  0.0664   0.586  0.232
## 6 Caspar    2011      -124.     39.4      NA        NA    NA       NA     1.03
## # ... with abbreviated variable names 1: mean_OUTER, 2: se_INNER, 3: se_OUTER
```

```
# kelp density predictions at 120m resolution
pred_120m <- read.csv(paste(d.dir, 'NC_kelp_density_predictions_120m.csv', sep ='/')) %>%
  mutate_at(vars(year, site_name), list(as.factor))

kelp_data_120m <- left_join(pred_120m, obs, by = c('site_name', 'year')) %>%
  group_by(site_name) %>%
  arrange(year, .by_group = TRUE) %>%
  relocate(fit, .after = last_col())
head(kelp_data_120m)
```

```
## # A tibble: 6 x 9
## # Groups:   site_name [1]
##   site_name year  longitude latitude mean_INNER mean_OU~1 se_IN~2 se_OU~3    fit
##   <fct>     <fct>     <dbl>    <dbl>      <dbl>     <dbl>   <dbl>   <dbl>  <dbl>
## 1 Caspar    2006      -124.     39.4      NA        NA    NA       NA     0.226
```

```
## 2 Caspar    2007      -124.     39.4      NA        NA    NA       NA      3.13
## 3 Caspar    2008      -124.     39.4       4.38      3.03  0.150    0.996  4.35
## 4 Caspar    2009      -124.     39.4      NA        NA    NA       NA     18.8
## 5 Caspar    2010      -124.     39.4       4.37      4.17  0.0664   0.586  0.865
## 6 Caspar    2011      -124.     39.4      NA        NA    NA       NA      3.03
## # ... with abbreviated variable names 1: mean_OUTER, 2: se_INNER, 3: se_OUTER
```

```
# kelp density predictions at 150m resolution
pred_150m <- read.csv(paste(d.dir, 'NC_kelp_density_predictions_150m.csv', sep ='/')) %>%
  mutate_at(vars(year, site_name), list(as.factor))

kelp_data_150m <- left_join(pred_150m, obs, by = c('site_name', 'year')) %>%
  group_by(site_name) %>%
  arrange(year, .by_group = TRUE) %>%
  relocate(fit, .after = last_col())
head(kelp_data_150m)
```

```
## # A tibble: 6 x 9
## # Groups:   site_name [1]
##   site_name year  longitude latitude mean_INNER mean_OU~1 se_IN~2 se_OU~3    fit
##   <fct>     <fct>     <dbl>    <dbl>      <dbl>     <dbl>   <dbl>   <dbl>  <dbl>
## 1 Caspar    2006      -124.     39.4      NA        NA    NA       NA      0.228
## 2 Caspar    2007      -124.     39.4      NA        NA    NA       NA      3.16
## 3 Caspar    2008      -124.     39.4       4.38      3.03  0.150    0.996  4.40
## 4 Caspar    2009      -124.     39.4      NA        NA    NA       NA     19.0
## 5 Caspar    2010      -124.     39.4       4.37      4.17  0.0664   0.586  0.871
## 6 Caspar    2011      -124.     39.4      NA        NA    NA       NA      3.06
## # ... with abbreviated variable names 1: mean_OUTER, 2: se_INNER, 3: se_OUTER
```

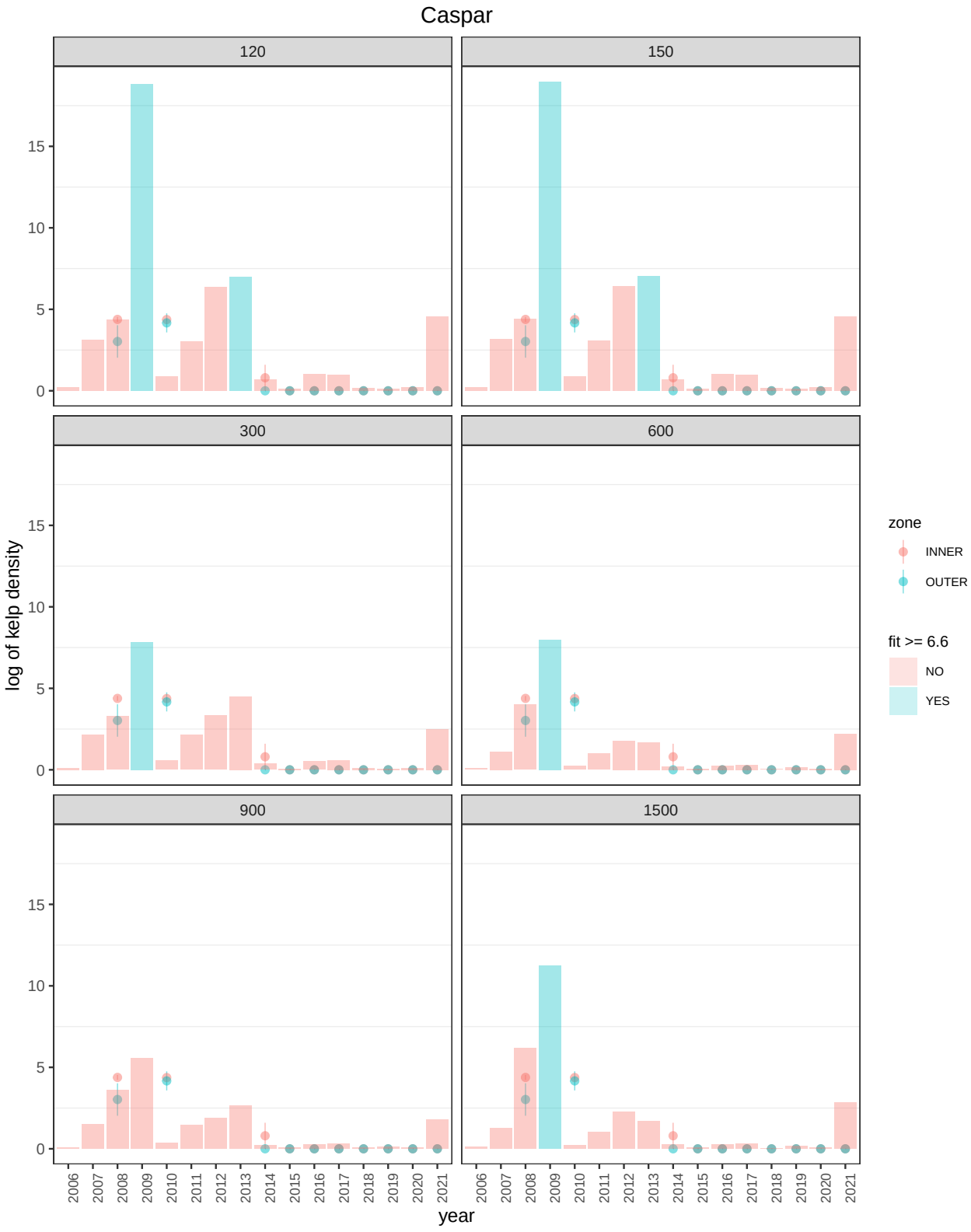
## Plotting

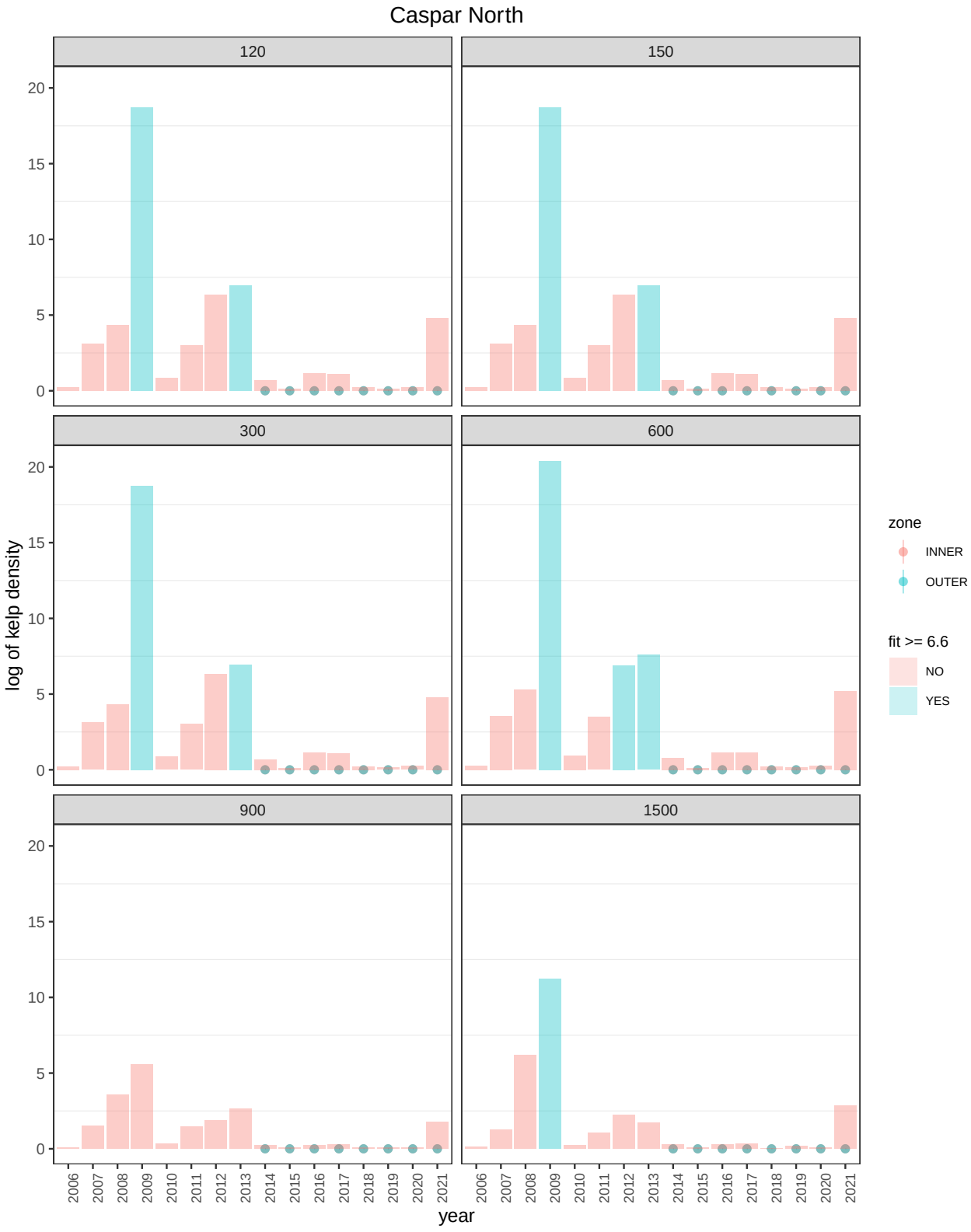
Plot log of kelps density vs year for each site at different resolutions.

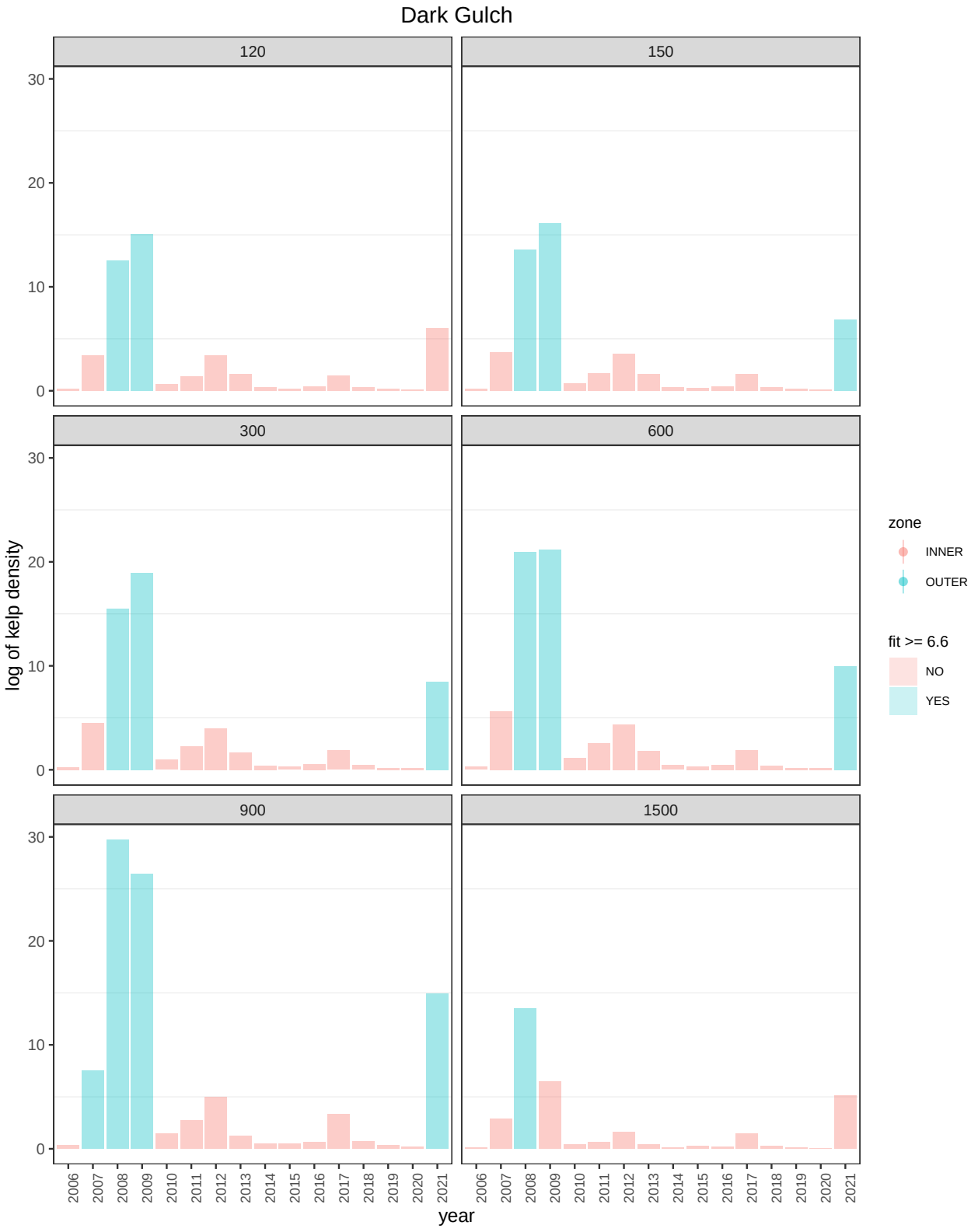
```
sites <- unique(kelp_data_300m$site_name)
sites <- sites[-c(5, 7, 12, 20, 24)]
res <- c(120, 150, 300, 600, 900, 1500)

kelp_longer_300m <- kelp_data_300m %>%
  dplyr::select(-c(longitude, latitude)) %>%
  pivot_longer(
    -c('site_name', 'year', 'fit'),
    names_to = c('.value', 'zone'),
    names_sep = '_'
    ) %>%
  mutate(resolution = as.factor(300))

kelp_longer_600m <- kelp_data_600m %>%
  dplyr::select(-c(longitude, latitude)) %>%
  pivot_longer(
    -c('site_name', 'year', 'fit'),
    names_to = c('.value', 'zone'),
    names_sep = '_'
```

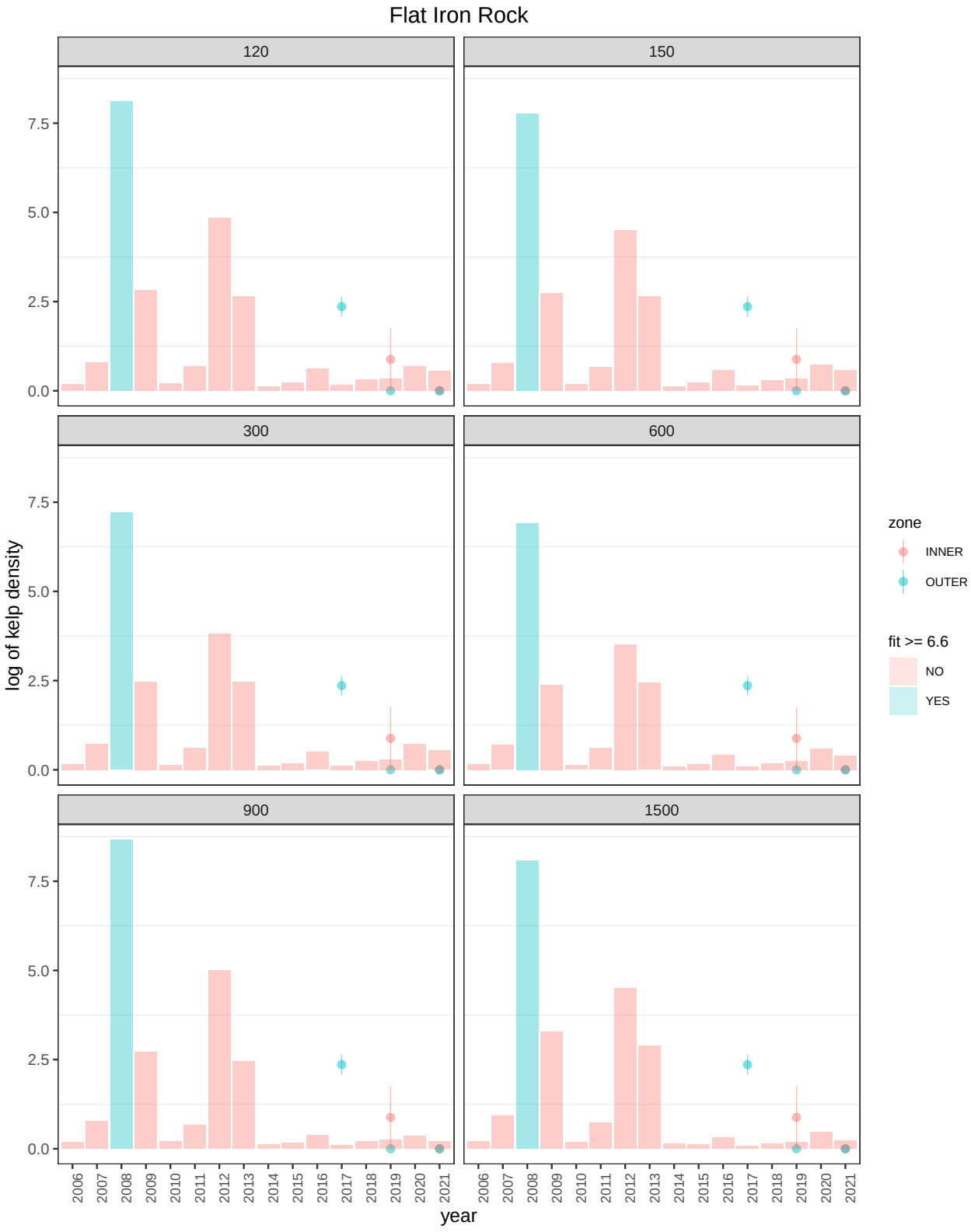
```
    ) %>%
  mutate(resolution = as.factor(600))

kelp_longer_900m <- kelp_data_900m %>%
  dplyr::select(-c(longitude, latitude)) %>%
  pivot_longer(
    -c('site_name', 'year', 'fit'),
    names_to = c('.value', 'zone'),
    names_sep = '_'
    ) %>%
  mutate(resolution = as.factor(900))

kelp_longer_1500m <- kelp_data_1500m %>%
  dplyr::select(-c(longitude, latitude)) %>%
  pivot_longer(
    -c('site_name', 'year', 'fit'),
    names_to = c('.value', 'zone'),
    names_sep = '_'
    ) %>%
  mutate(resolution = as.factor(1500))

kelp_longer_120m <- kelp_data_120m %>%
  dplyr::select(-c(longitude, latitude)) %>%
  pivot_longer(
    -c('site_name', 'year', 'fit'),
    names_to = c('.value', 'zone'),
    names_sep = '_'
    ) %>%
  mutate(resolution = as.factor(120))

kelp_longer_150m <- kelp_data_150m %>%
  dplyr::select(-c(longitude, latitude)) %>%
  pivot_longer(
    -c('site_name', 'year', 'fit'),
    names_to = c('.value', 'zone'),
    names_sep = '_'
    ) %>%
  mutate(resolution = as.factor(150))

kelp_longer <- rbind(kelp_longer_120m, kelp_longer_150m,
                     kelp_longer_300m, kelp_longer_600m,
                     kelp_longer_900m, kelp_longer_1500m)

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')),
```

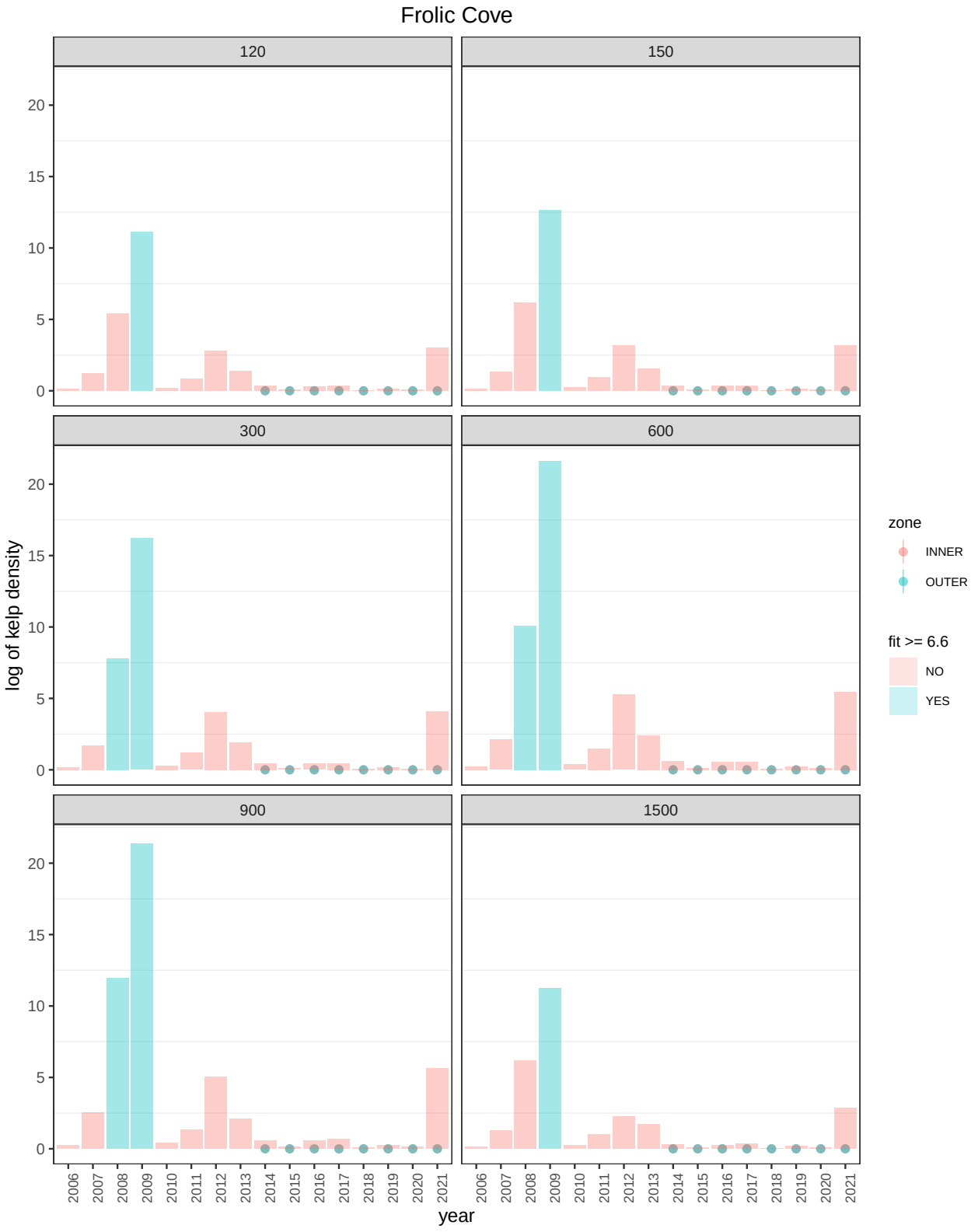
```
            stat = 'identity', position = 'dodge', alpha = 0.2) +
    facet_wrap(. ~ resolution, nrow = 3) +
    theme_bw() +
    theme(axis.text.x = element_text(angle = 90, size = 8),
          plot.title = element_text(hjust = 0.5),
          panel.grid.major = element_blank(),
          legend.title = element_text(size = 9),
          legend.text = element_text(size = 7)) +
    labs(y = 'log of kelp density', title = i, fill = 'fit >= 6.6')
  print(plot)
}
```

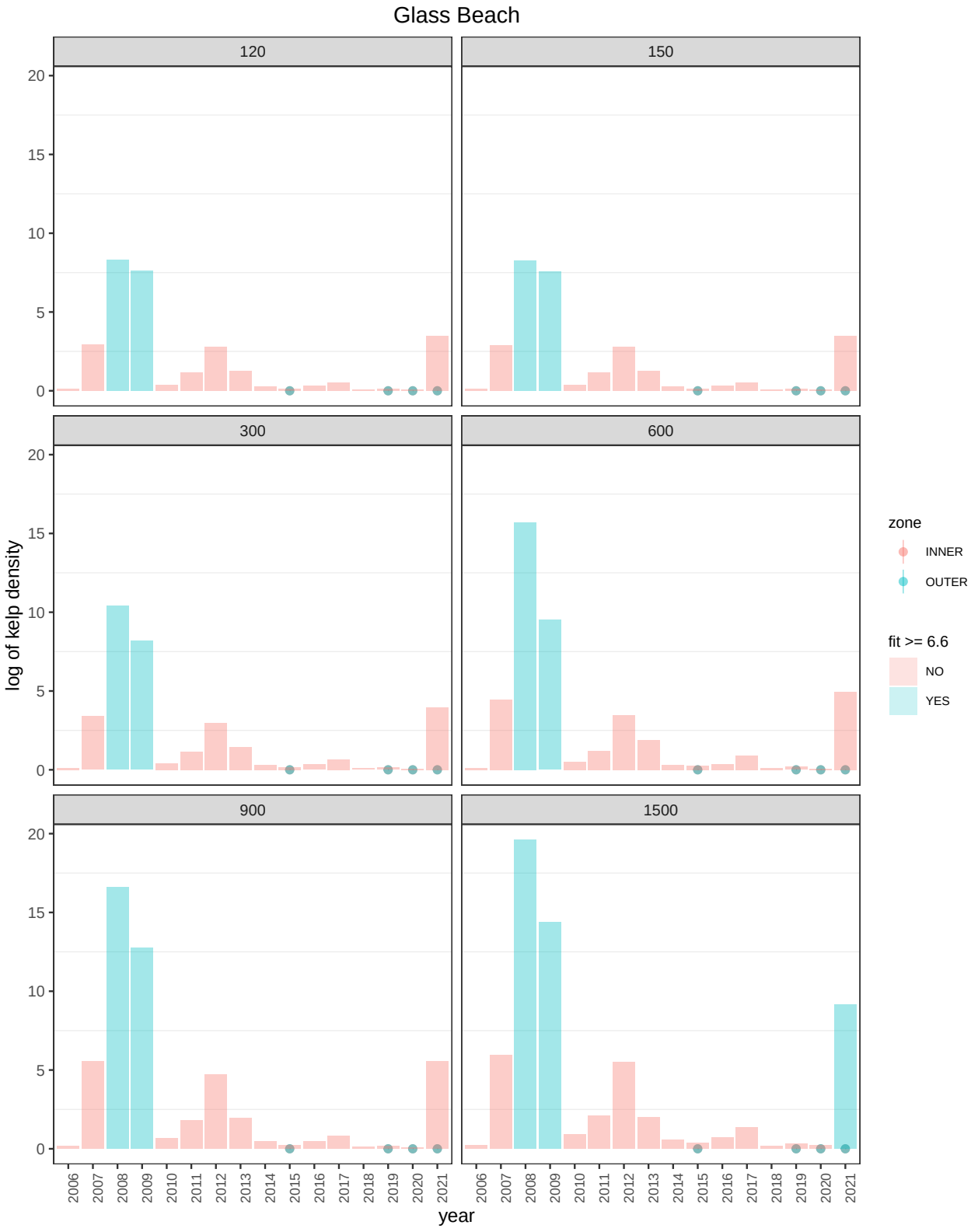

Caspar
120
150
300
600
900
1500
log of kelp density
0
5
10
15
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

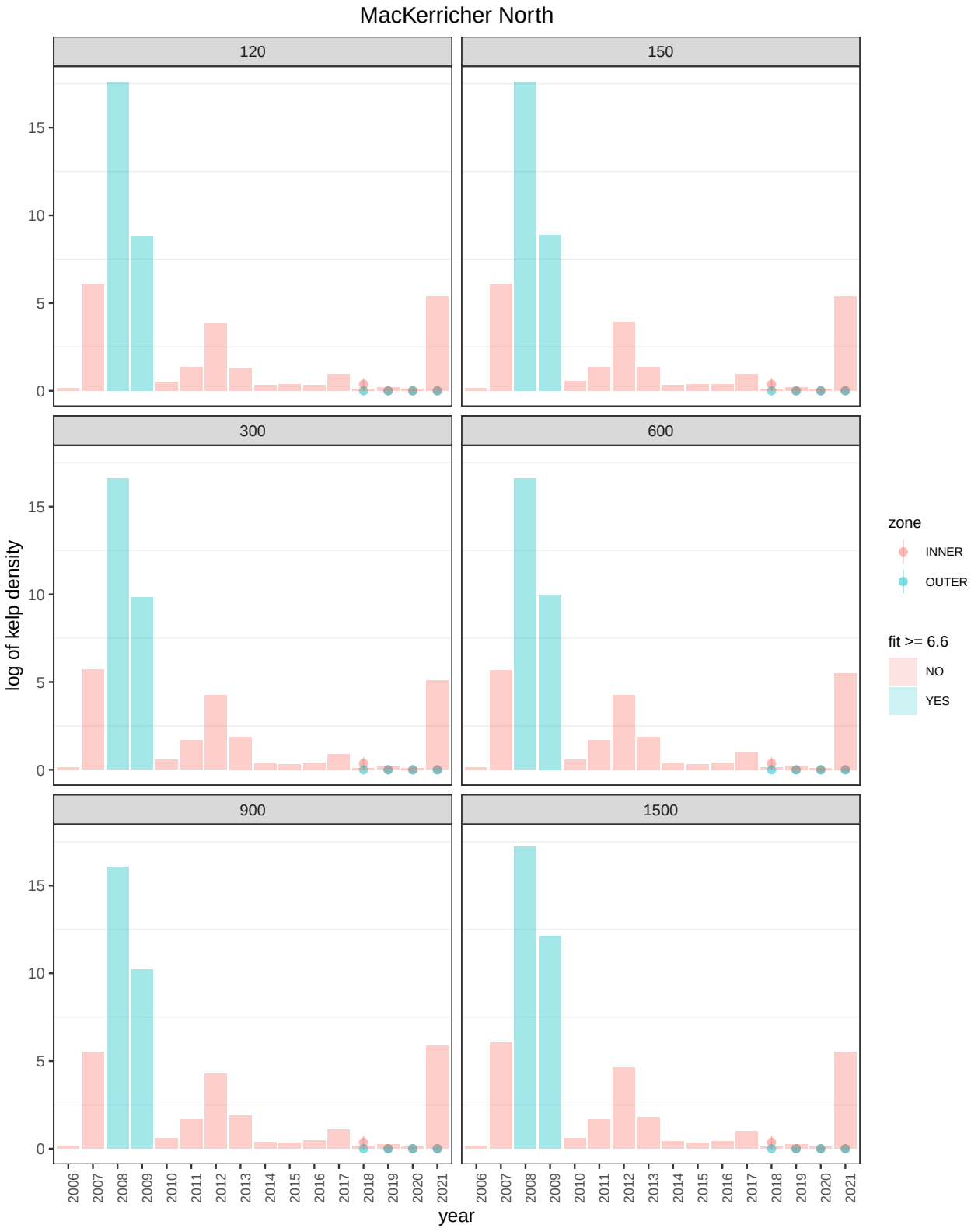

Caspar North
120
150
300
600
900
1500
log of kelp density
0
5
10
15
20
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

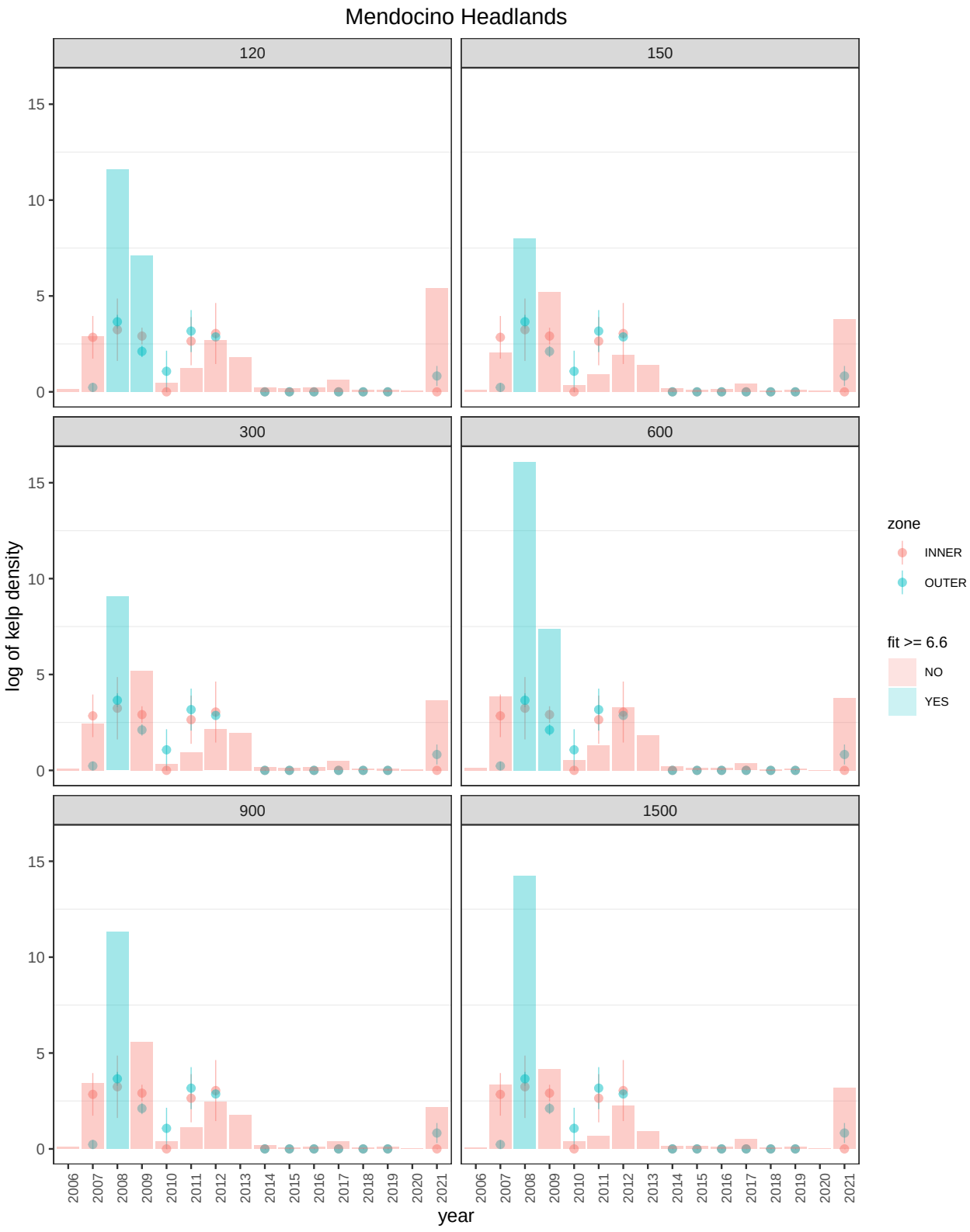

Dark Gulch
120
150
300
600
900
1500
log of kelp density
0
10
20
30
year
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
zone
INNER
OUTER
fit >= 6.6
NO
YES

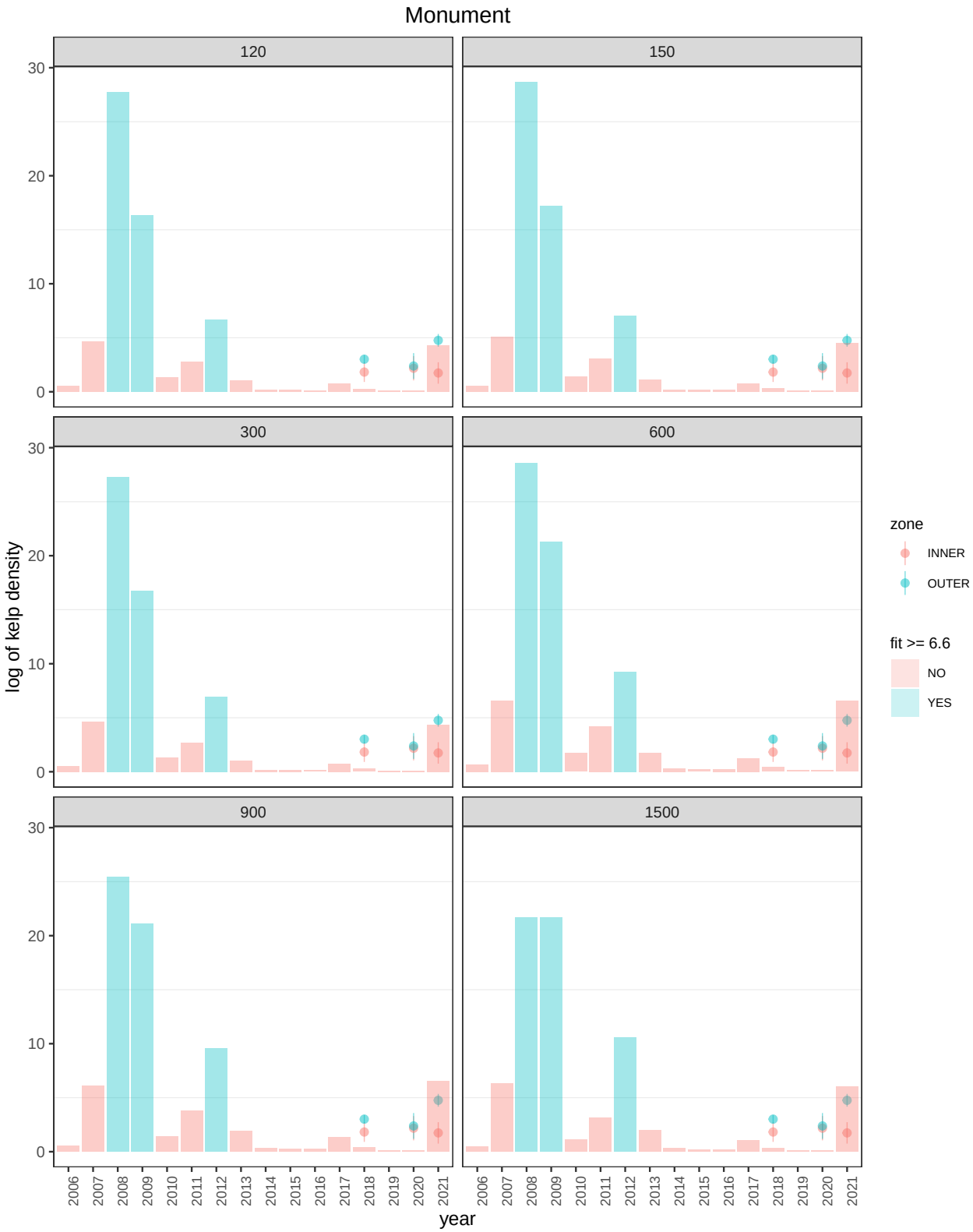

Flat Iron Rock
120
150
300
600
900
1500
log of kelp density
7.5
5.0
2.5
0.0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

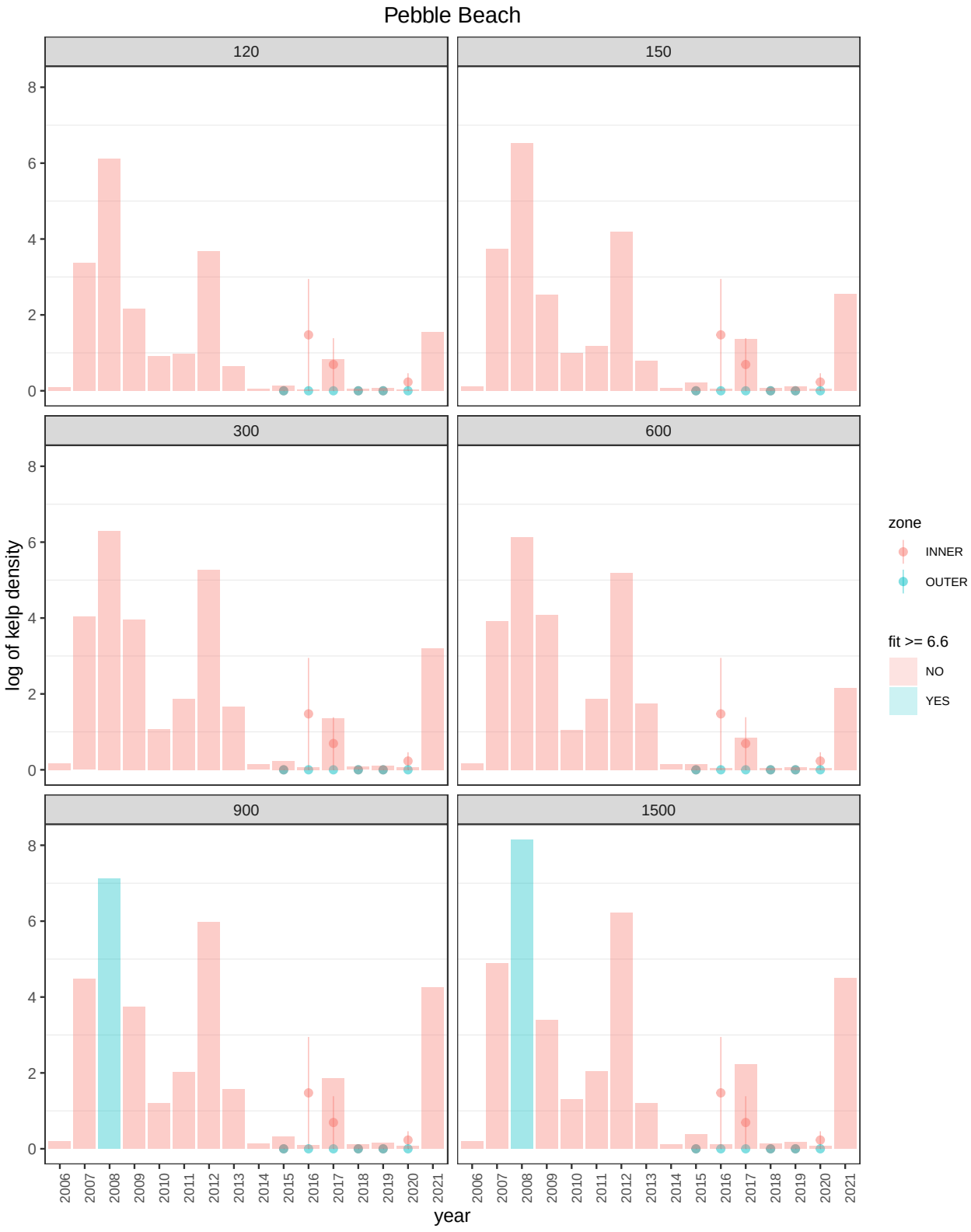

Frolic Cove
120
150
300
600
900
1500
log of kelp density
0
5
10
15
20
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

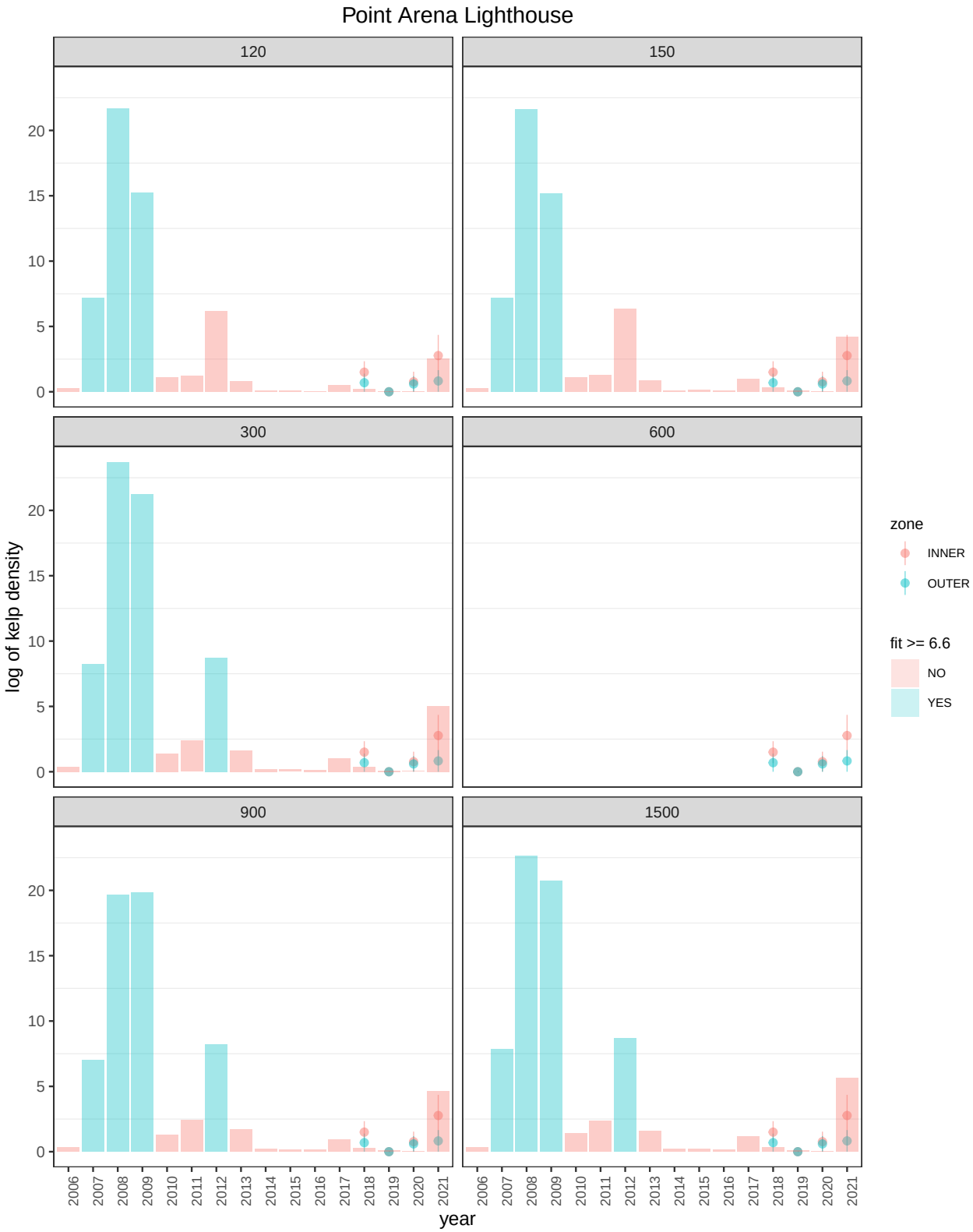

Glass Beach
120
150
300
600
900
1500
log of kelp density
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

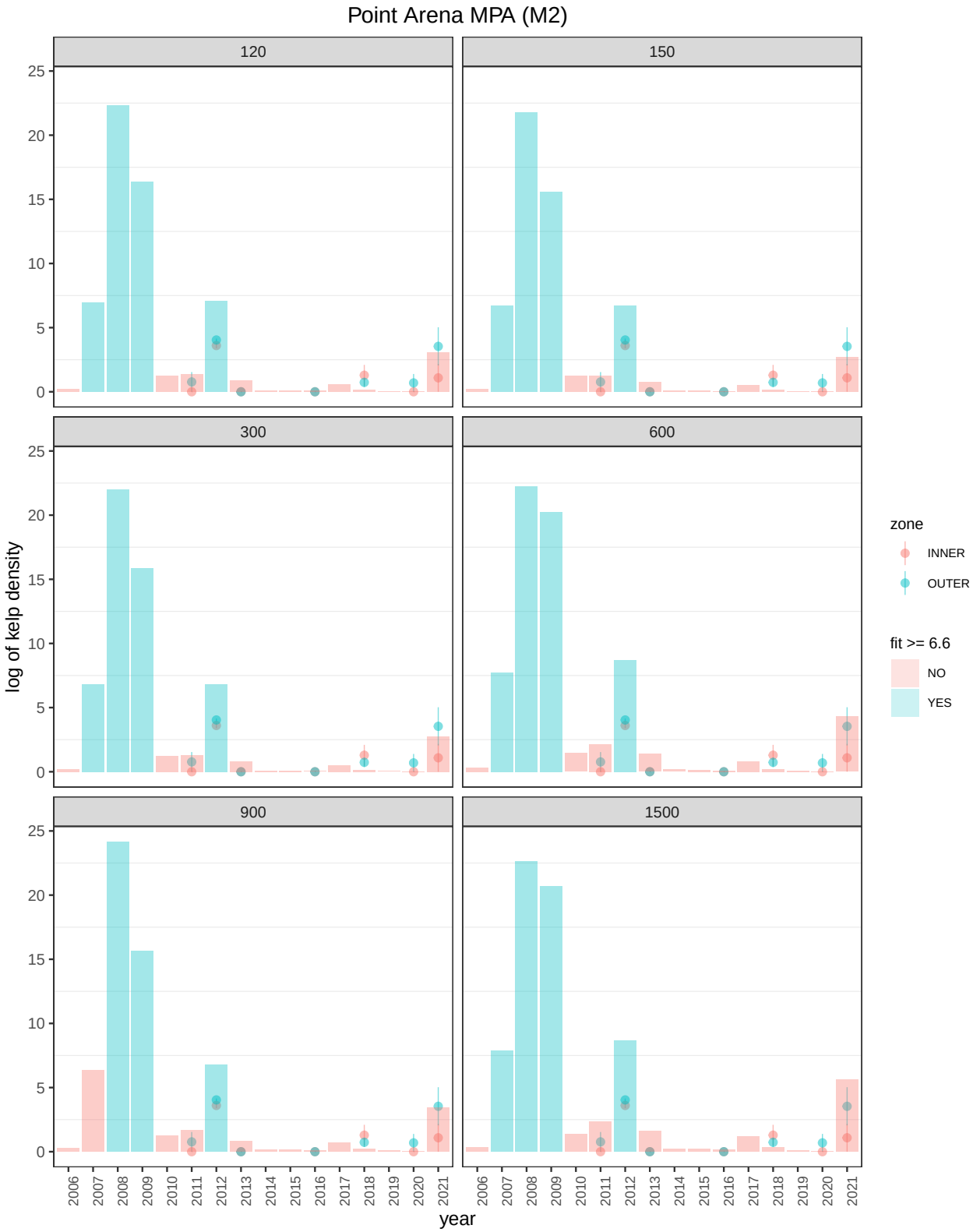

MacKerricher North
120
150
300
600
900
1500
log of kelp density
0
5
10
15
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

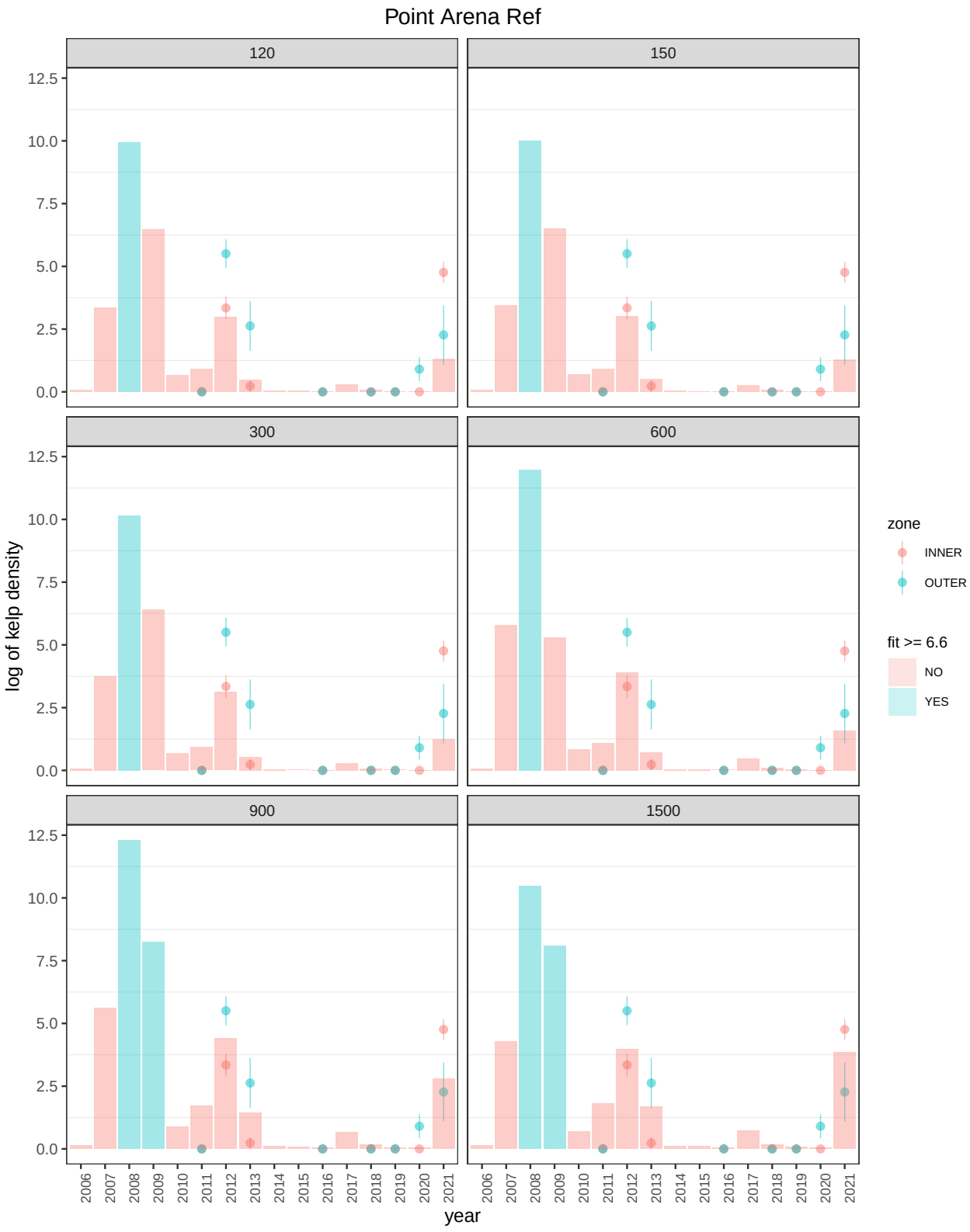

Mendocino Headlands
120
150
300
600
900
1500
log of kelp density
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

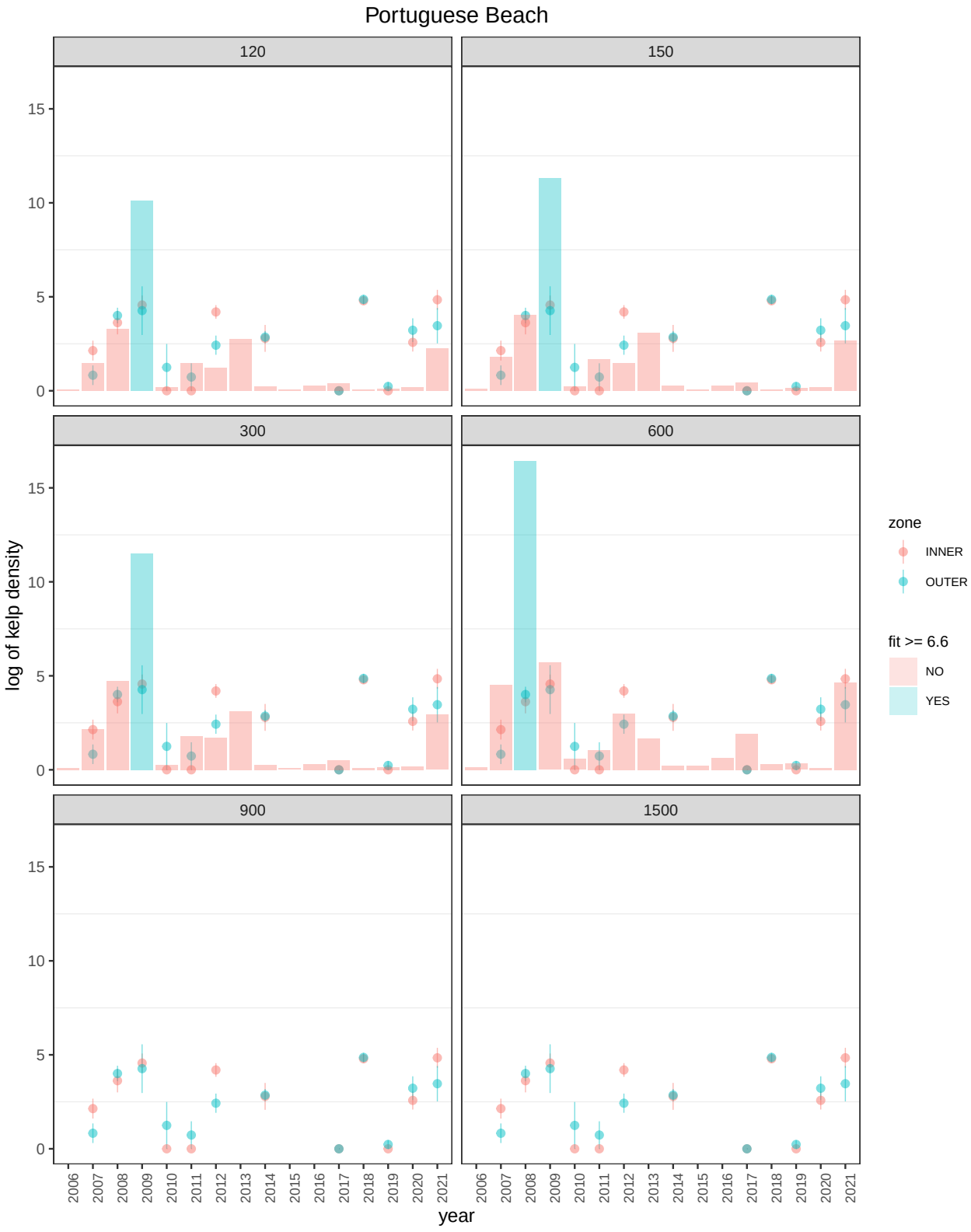

Monument
120
150
300
600
900
1500
log of kelp density
0
10
20
30
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

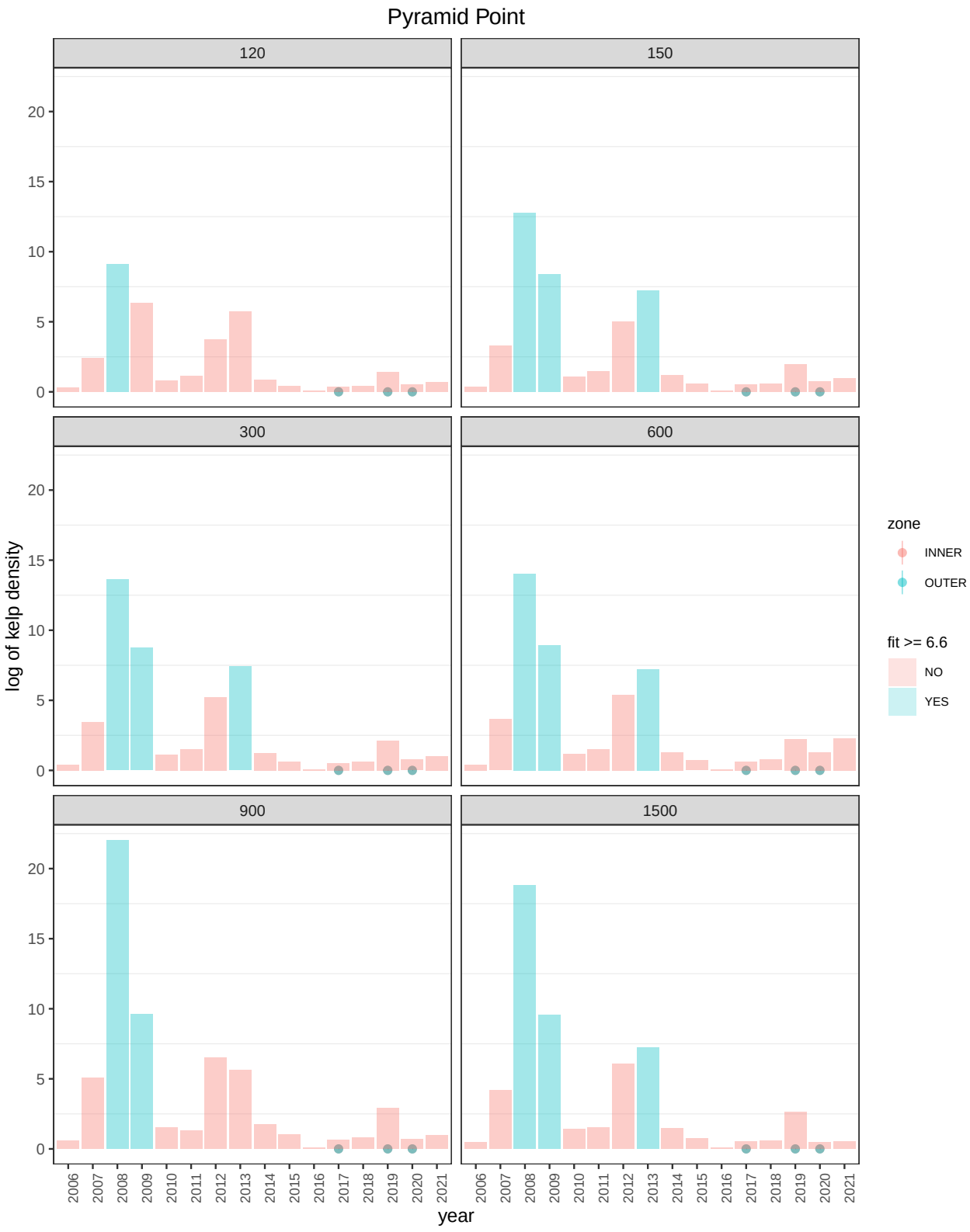

Pebble Beach
120
150
300
600
900
1500
log of kelp density
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

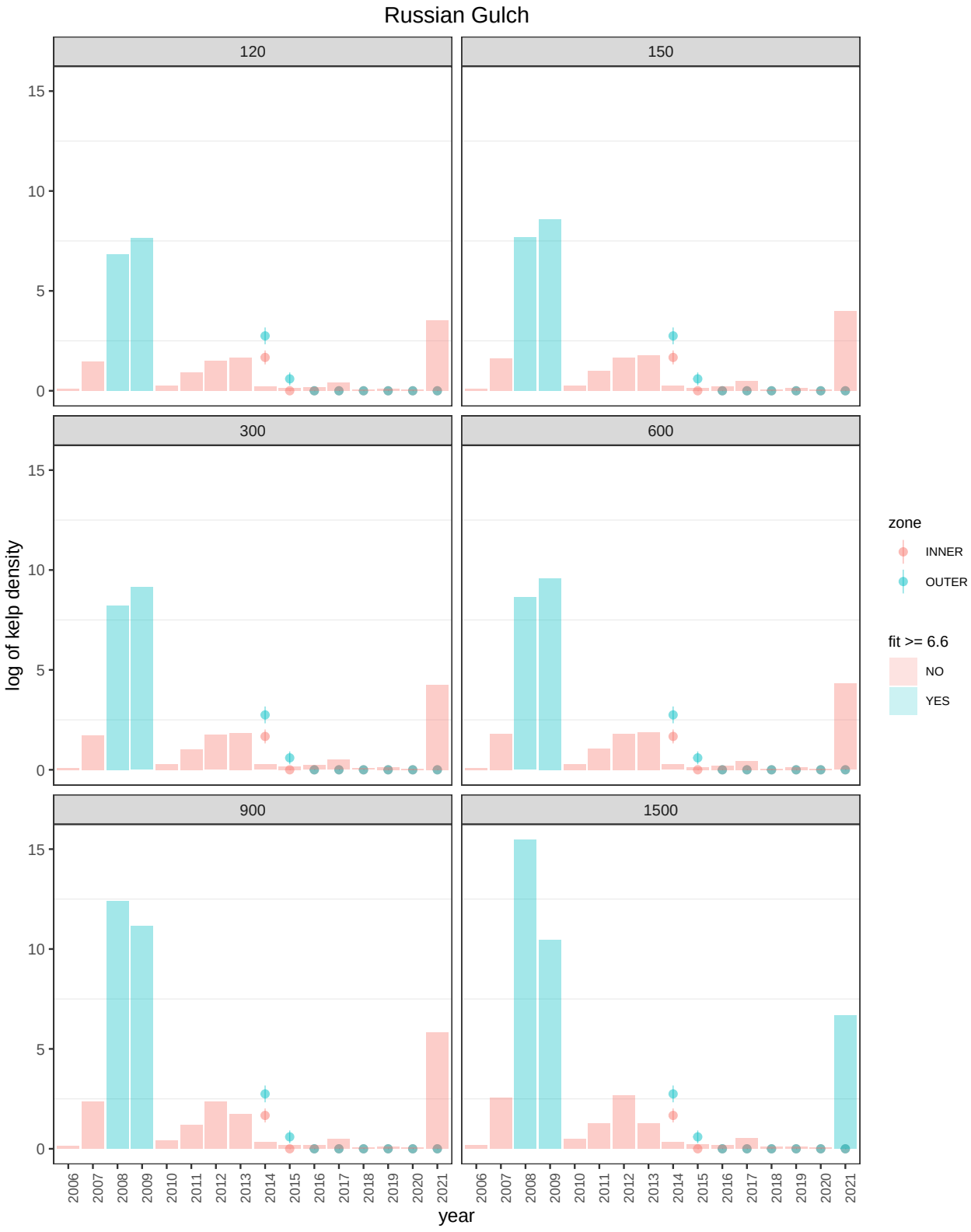

Point Arena Lighthouse
120
150
300
600
900
1500
log of kelp density
0
5
10
15
20
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

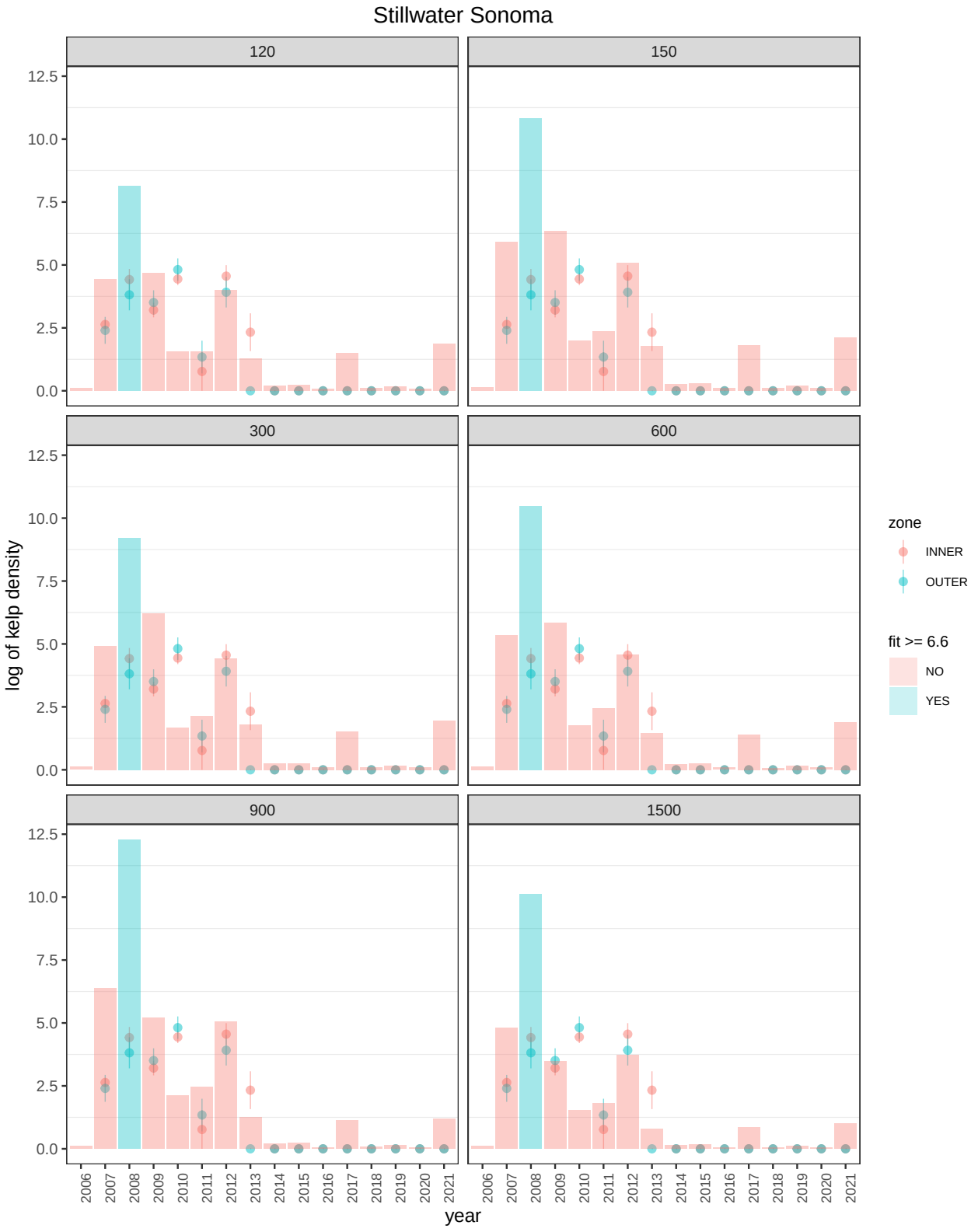

Point Arena MPA (M2)
120
150
300
600
900
1500
log of kelp density
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

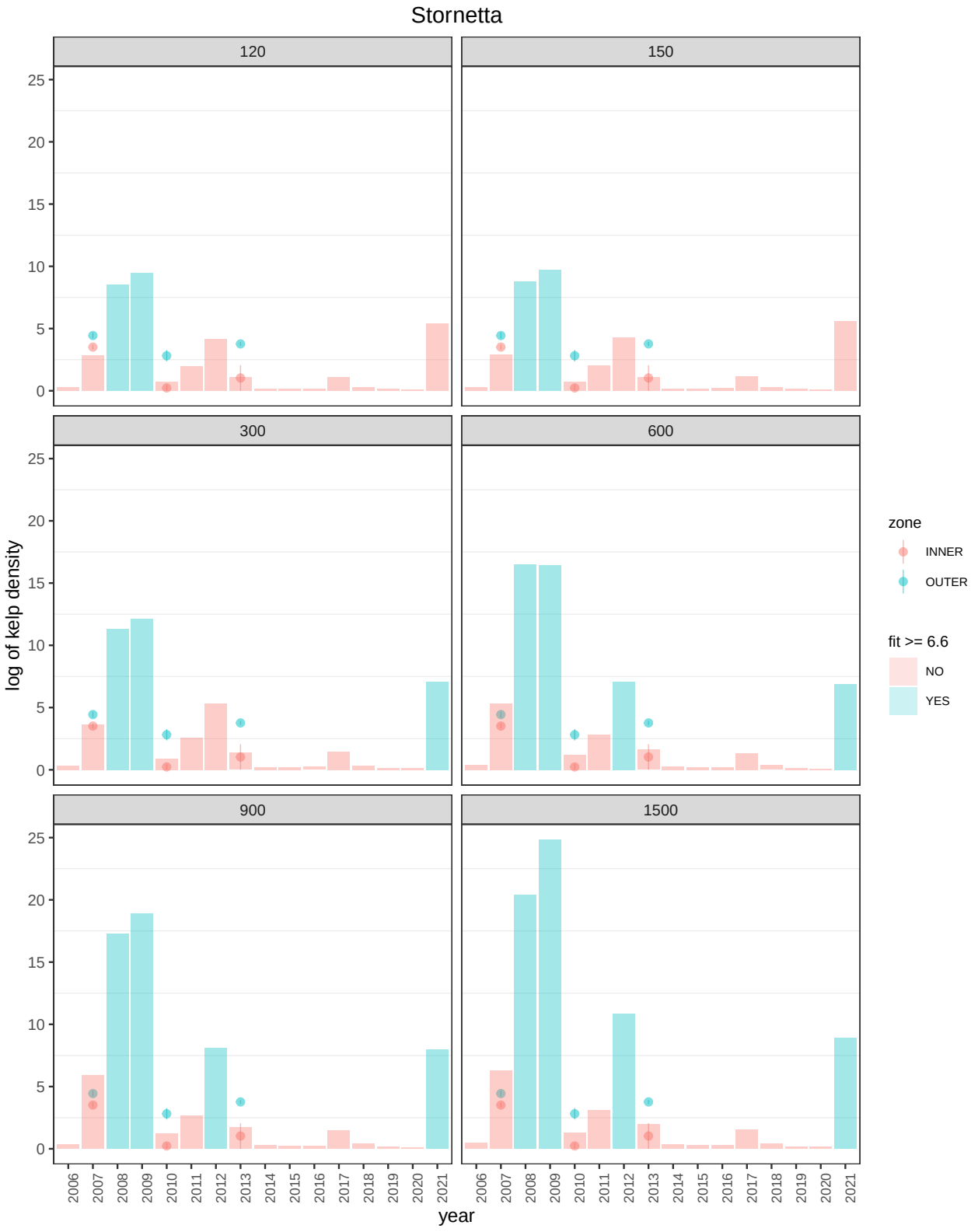

Point Arena Ref
120
150
300
600
900
1500
log of kelp density
12.5
10.0
7.5
5.0
2.5
0.0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

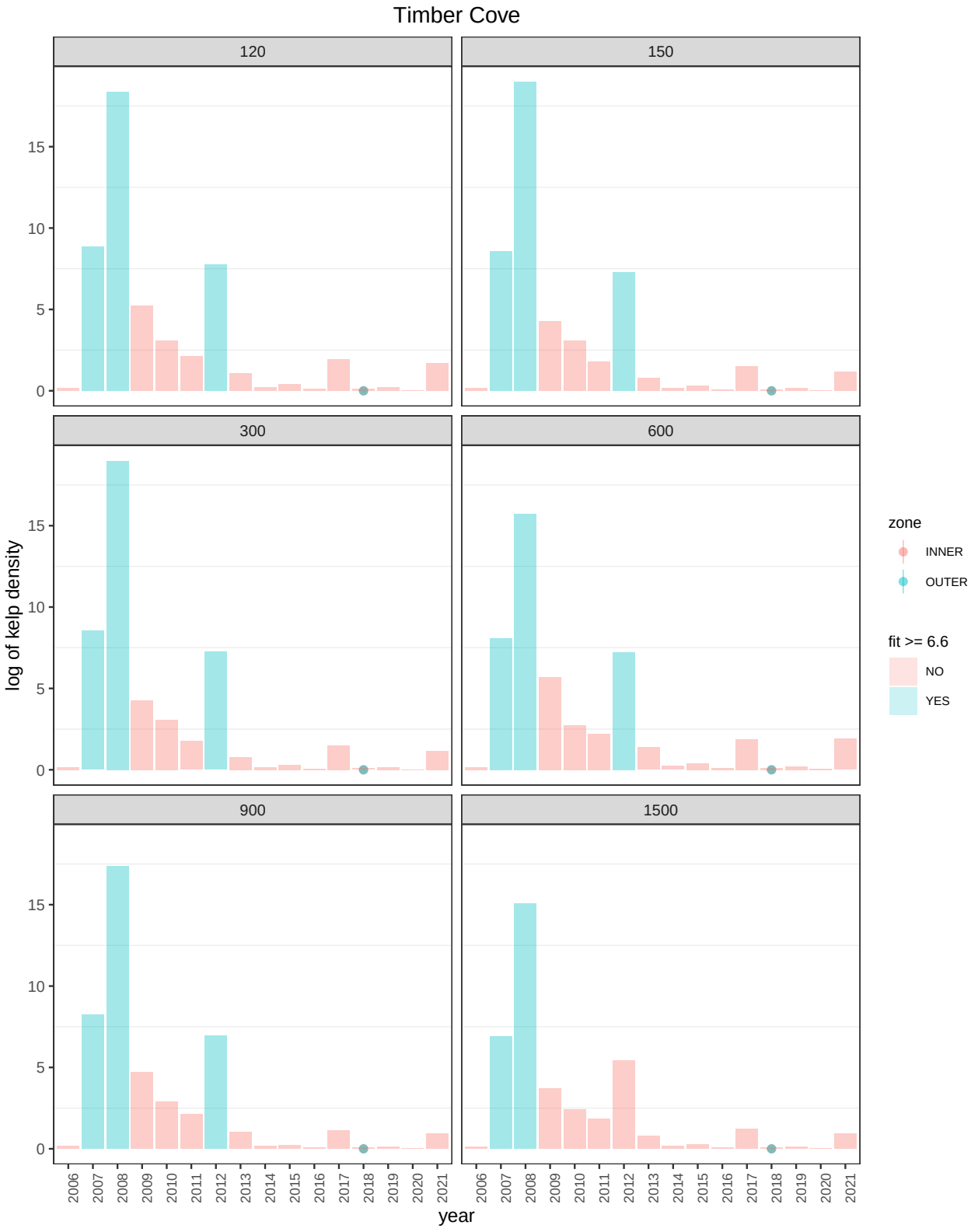

Portuguese Beach
120
150
300
600
900
1500
log of kelp density
0
5
10
15
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES

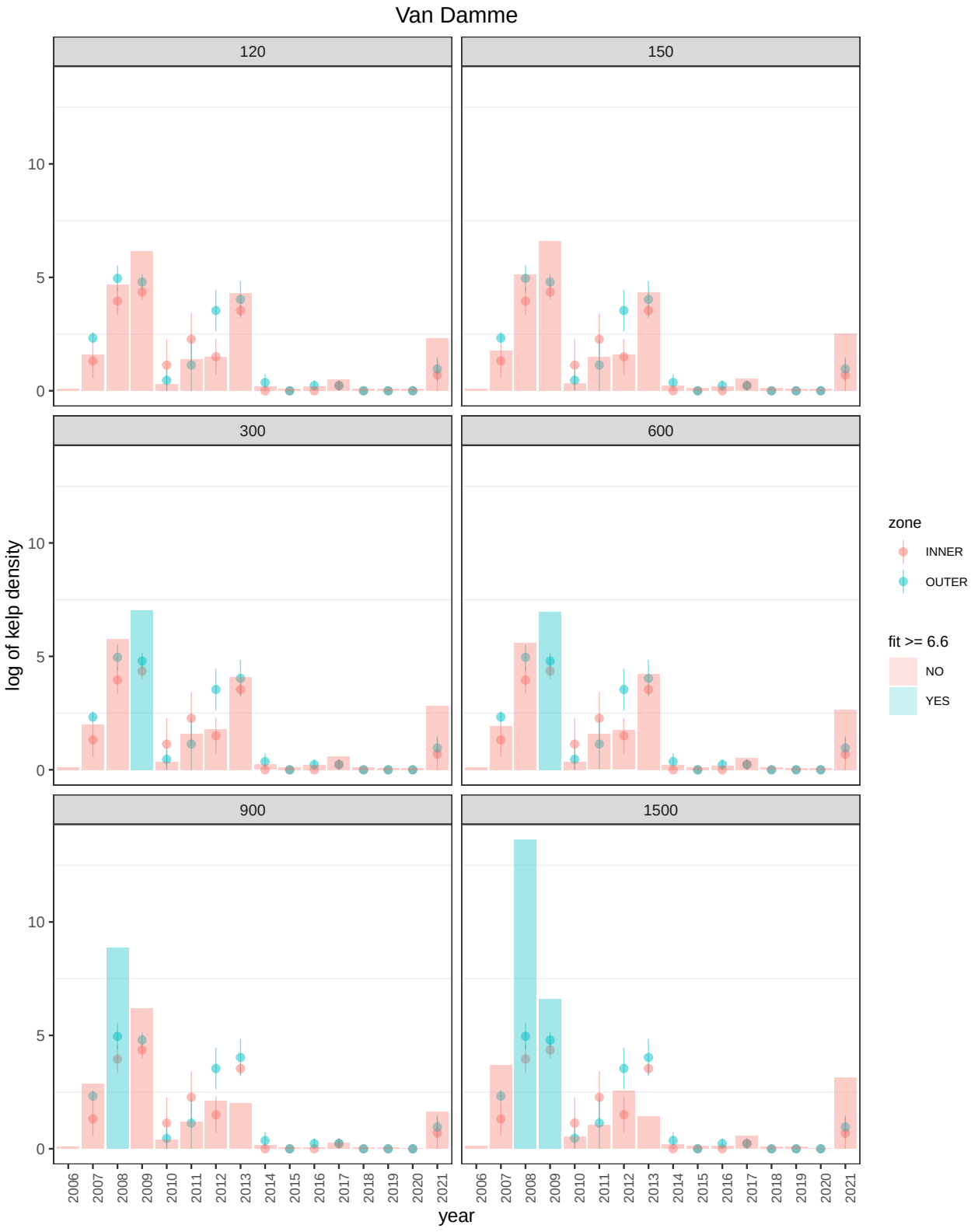

Pyramid Point
120
150
300
600
900
1500
log of kelp density
0
5
10
15
20
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO
YES


Russian Gulch
120
150
300
600
900
1500
log of kelp density
0
5
10
15
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


Stillwater Sonoma
120
150
300
600
900
1500
log of kelp density
12.5
10.0
7.5
5.0
2.5
0.0
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


Stornetta
120
150
300
600
900
1500
log of kelp density
year
zone
INNER
OUTER
fit >= 6.6
NO
YES


Timber Cove
120
150
300
600
900
1500
log of kelp density
0
5
10
15
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


Van Damme
120
150
300
600
900
1500
log of kelp density
0
5
10
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