SURE Project

September 21, 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')
r1.dir <- here('spatial_data/sp_predictions_300m')
r2.dir <- here('spatial_data/sp_predictions_150m')
r3.dir <- here('spatial_data/sp_predictions_600m')
r4.dir <- here('spatial_data/sp_predictions_900m')
r5.dir <- here('spatial_data/sp_predictions_120m')
r6.dir <- here('spatial_data/sp_predictions_1500m')

# 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).

```r
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.

```r
# kelp density predictions at 300m resolution ----

# 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(r1.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)
```

```
##        site_name year          fit
## 1         Caspar 2006 8.715952e-05
## 2   Caspar North 2006 1.153930e-04
## 3     Dark Gulch 2006 1.639244e-05
## 4 Flat Iron Rock 2006 1.293419e-05
## 5      Fort Ross 2006          NaN
## 6    Frolic Cove 2006 2.514721e-05
```

```r
# 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_300m.csv'), row.names = FALSE)
```

```
# kelp density predictions at 150m resolution ----

# 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(r2.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)
```

```
##        site_name year          fit
## 1         Caspar 2006 1.247151e-04
## 2   Caspar North 2006 1.158852e-04
## 3     Dark Gulch 2006 2.009678e-05
## 4 Flat Iron Rock 2006 1.248947e-05
## 5      Fort Ross 2006          NaN
## 6    Frolic Cove 2006 2.890074e-05
```

```
# 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_150m.csv'), row.names = FALSE)
```

```
# kelp density predictions at 600m resolution ----

# 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())
```

```r
for (i in c(2006:2021)) {
  rast <- rast(paste0(r3.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)
```

```
##        site_name year          fit
## 1         Caspar 2006 4.765976e-05
## 2   Caspar North 2006 1.033656e-04
## 3     Dark Gulch 2006 1.581757e-05
## 4 Flat Iron Rock 2006 1.356833e-05
## 5      Fort Ross 2006          NaN
## 6    Frolic Cove 2006 2.109280e-05
```

```r
# 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_600m.csv'), row.names = FALSE)
```

```r
# kelp density predictions at 900m resolution

# 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(r4.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)
```

```
##        site_name year          fit
## 1         Caspar 2006 5.600709e-05
## 2   Caspar North 2006 5.600709e-05
## 3     Dark Gulch 2006 8.153335e-06
## 4 Flat Iron Rock 2006 1.218360e-05
```

```
## 5      Fort Ross 2006          NaN
## 6    Frolic Cove 2006 2.195355e-05
```

```
# 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_900m.csv'), row.names = FALSE)
```

```
# kelp density predictions at 120m resolution

# 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(r5.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)
```

```
##        site_name year          fit
## 1         Caspar 2006 1.249614e-04
## 2   Caspar North 2006 1.153889e-04
## 3     Dark Gulch 2006 2.207590e-05
## 4 Flat Iron Rock 2006 1.211293e-05
## 5      Fort Ross 2006          NaN
## 6    Frolic Cove 2006 3.023131e-05
```

```
# 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)
```

```
# kelp density predictions at 1500m resolution

# 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')
```

```r
# 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)
```

```
##        site_name year          fit
## 1         Caspar 2006 3.185520e-05
## 2   Caspar North 2006 3.185520e-05
## 3     Dark Gulch 2006 1.221586e-05
## 4 Flat Iron Rock 2006 1.352611e-05
## 5      Fort Ross 2006          NaN
## 6    Frolic Cove 2006 3.185520e-05
```

```r
# 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_1500m.csv'), row.names = FALSE)
```

Comparison

```r
# 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_O~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     8.72e-5
## 2 Caspar    2007      -124.     39.4      NA       NA    NA       NA     2.31e-5
## 3 Caspar    2008      -124.     39.4       4.38     3.03  0.150    0.996 9.86e-6
## 4 Caspar    2009      -124.     39.4      NA       NA    NA       NA     7.44e-6
```

```
## 5 Caspar    2010      -124.     39.4       4.37     4.17  0.0664   0.586 7.67e-5
## 6 Caspar    2011      -124.     39.4      NA       NA    NA       NA     4.43e-5
## # ... 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_O~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     1.25e-4
## 2 Caspar    2007      -124.     39.4      NA       NA    NA       NA     2.97e-5
## 3 Caspar    2008      -124.     39.4       4.38     3.03  0.150    0.996 1.31e-5
## 4 Caspar    2009      -124.     39.4      NA       NA    NA       NA     1.13e-5
## 5 Caspar    2010      -124.     39.4       4.37     4.17  0.0664   0.586 9.84e-5
## 6 Caspar    2011      -124.     39.4      NA       NA    NA       NA     5.66e-5
## # ... with abbreviated variable names 1: mean_OUTER, 2: se_INNER, 3: 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_O~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     4.77e-5
## 2 Caspar    2007      -124.     39.4      NA       NA    NA       NA     1.76e-5
## 3 Caspar    2008      -124.     39.4       4.38     3.03  0.150    0.996 7.04e-6
## 4 Caspar    2009      -124.     39.4      NA       NA    NA       NA     4.02e-6
## 5 Caspar    2010      -124.     39.4       4.37     4.17  0.0664   0.586 5.93e-5
## 6 Caspar    2011      -124.     39.4      NA       NA    NA       NA     3.78e-5
## # ... 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_O~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     5.60e-5
## 2 Caspar    2007      -124.     39.4      NA       NA    NA       NA     1.91e-5
## 3 Caspar    2008      -124.     39.4       4.38     3.03  0.150    0.996 8.12e-6
## 4 Caspar    2009      -124.     39.4      NA       NA    NA       NA     5.28e-6
## 5 Caspar    2010      -124.     39.4       4.37     4.17  0.0664   0.586 6.34e-5
## 6 Caspar    2011      -124.     39.4      NA       NA    NA       NA     4.19e-5
## # ... 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_O~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     1.25e-4
## 2 Caspar    2007      -124.     39.4      NA       NA    NA       NA     2.96e-5
## 3 Caspar    2008      -124.     39.4       4.38     3.03  0.150    0.996 1.31e-5
## 4 Caspar    2009      -124.     39.4      NA       NA    NA       NA     1.12e-5
## 5 Caspar    2010      -124.     39.4       4.37     4.17  0.0664   0.586 9.74e-5
## 6 Caspar    2011      -124.     39.4      NA       NA    NA       NA     5.60e-5
## # ... 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]
```

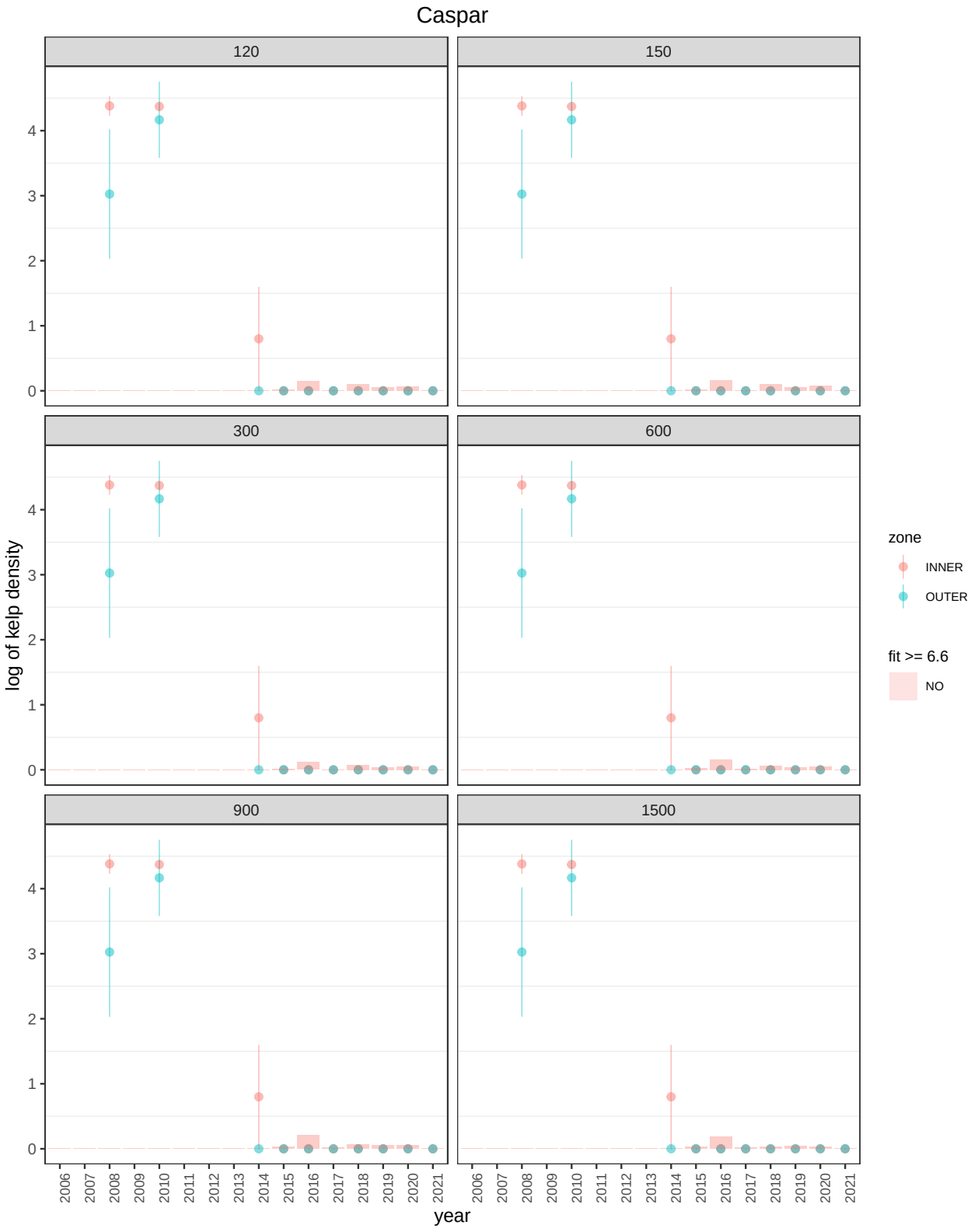
```
##   site_name year  longitude latitude mean_INNER mean_O~1 se_IN~2 se_OU~3     fit
##   <fct>     <fct>     <dbl>    <dbl>      <dbl>    <dbl>   <dbl>   <dbl>   <dbl>
## 1 Caspar    2006      -124.     39.4      NA       NA    NA       NA     3.19e-5
## 2 Caspar    2007      -124.     39.4      NA       NA    NA       NA     1.28e-5
## 3 Caspar    2008      -124.     39.4       4.38     3.03  0.150    0.996 5.17e-6
## 4 Caspar    2009      -124.     39.4      NA       NA    NA       NA     3.05e-6
## 5 Caspar    2010      -124.     39.4       4.37     4.17  0.0664   0.586 4.43e-5
## 6 Caspar    2011      -124.     39.4      NA       NA    NA       NA     3.19e-5
## # ... 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)

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_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_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_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_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_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 <- 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
1
2
3
4
2006
2007
2008
2009
2010
2011
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2018
2019
2020
2021
year
zone
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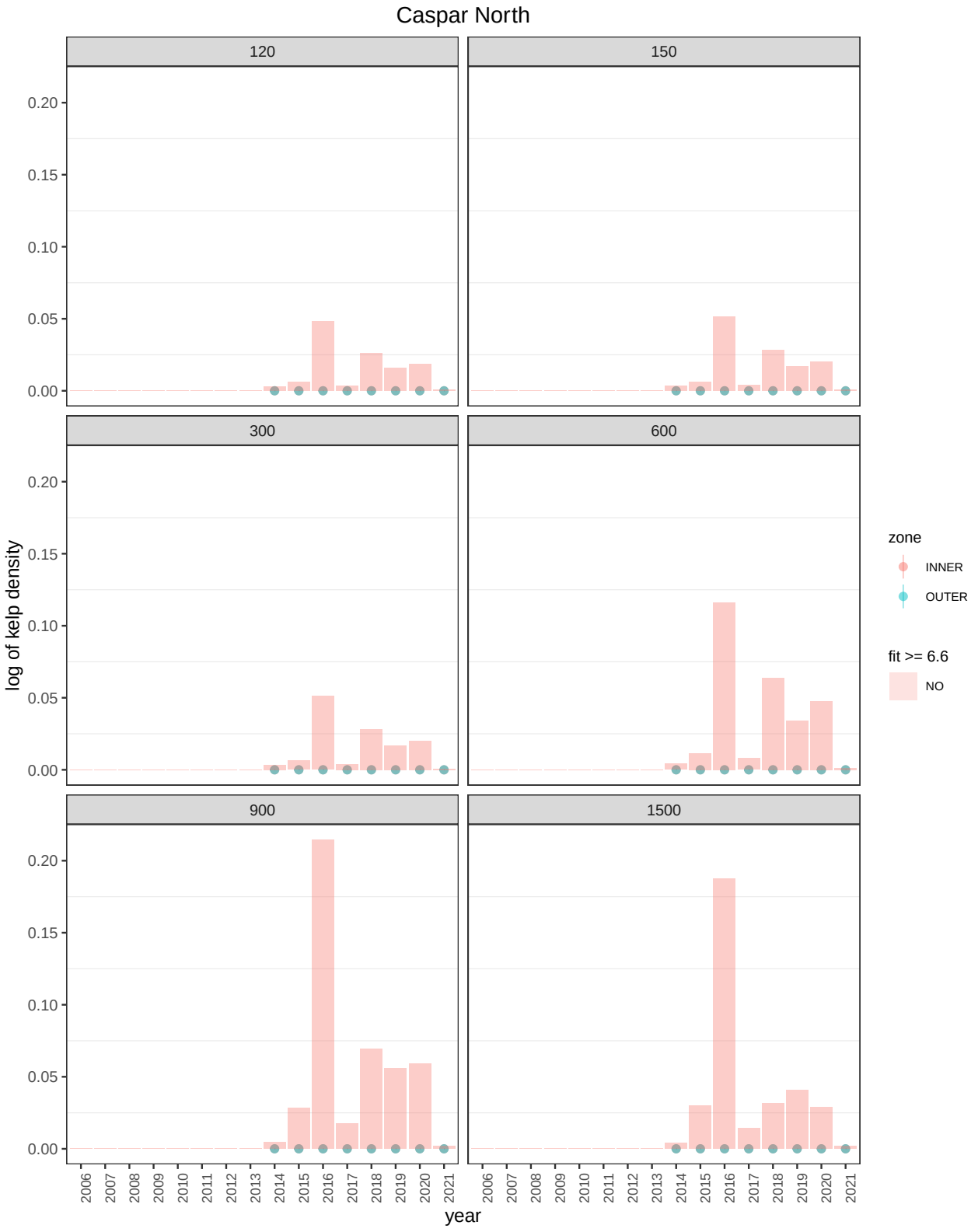
OUTER
fit >= 6.6
NO


Caspar North
120
150
300
600
900
1500
log of kelp density
0.20
0.15
0.10
0.05
0.00
2006
2007
2008
2009
2010
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2021
year
zone
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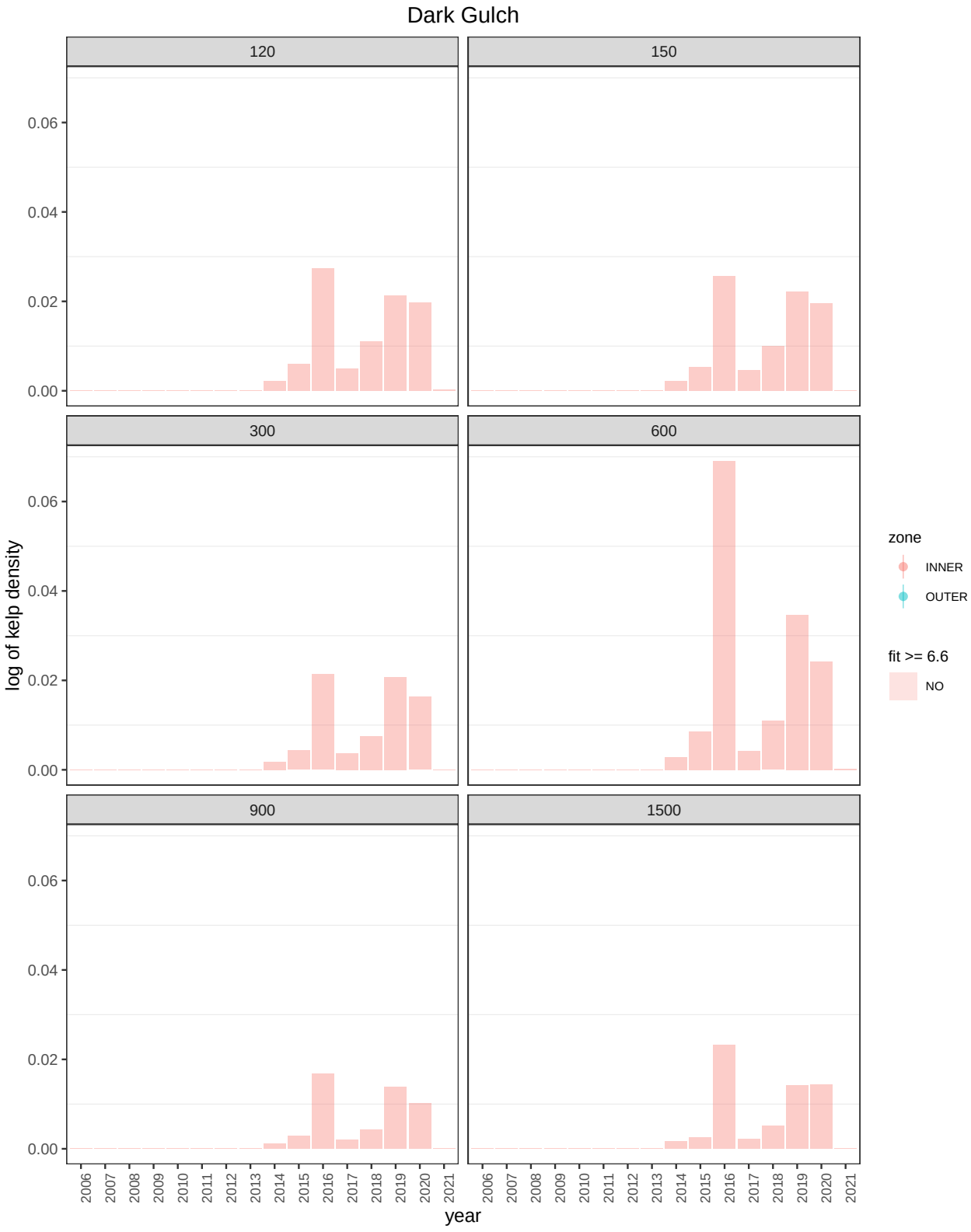
OUTER
fit >= 6.6
NO


Dark Gulch
120
150
300
600
900
1500
log of kelp density
0.00
0.02
0.04
0.06
year
2006
2007
2008
2009
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zone
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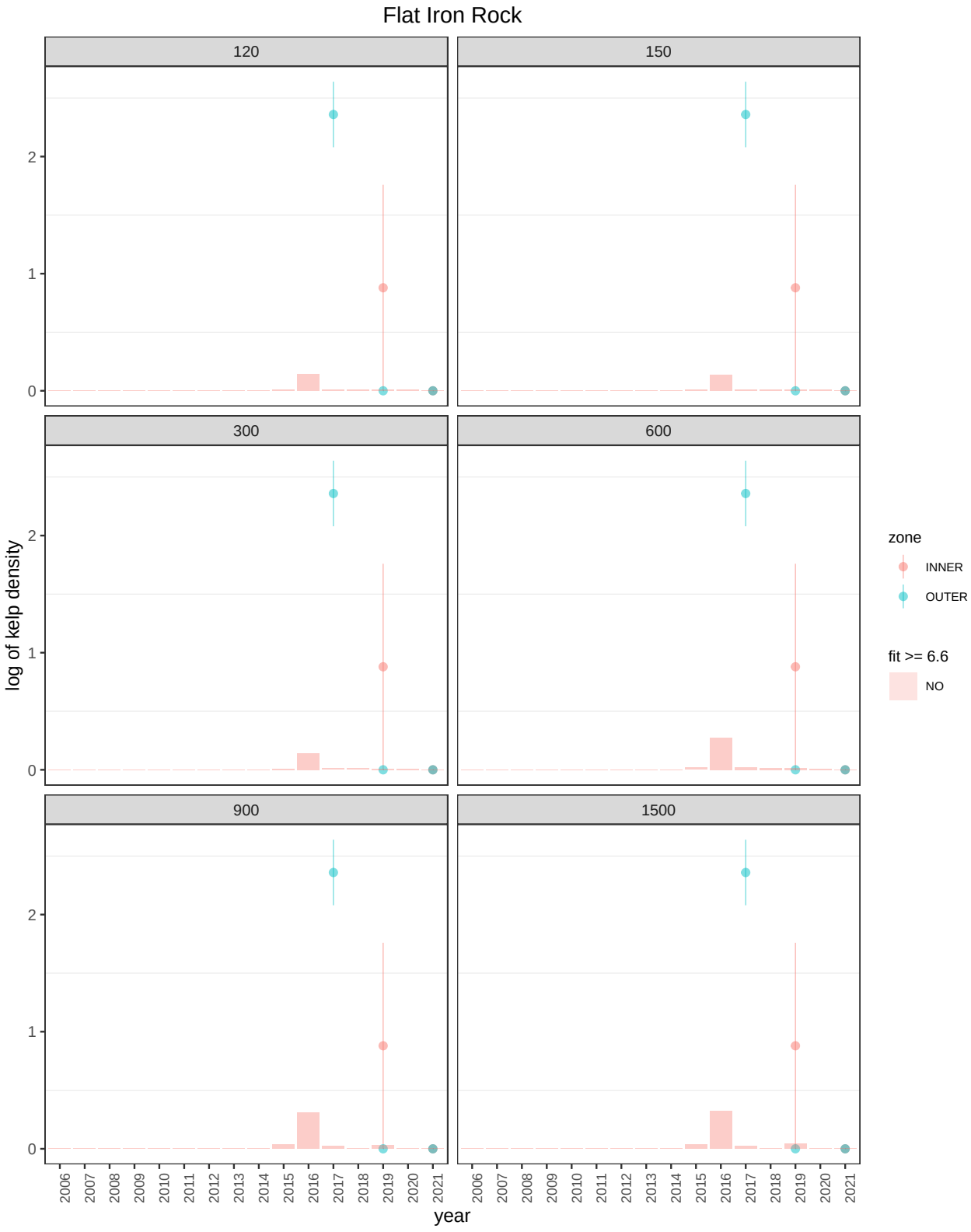
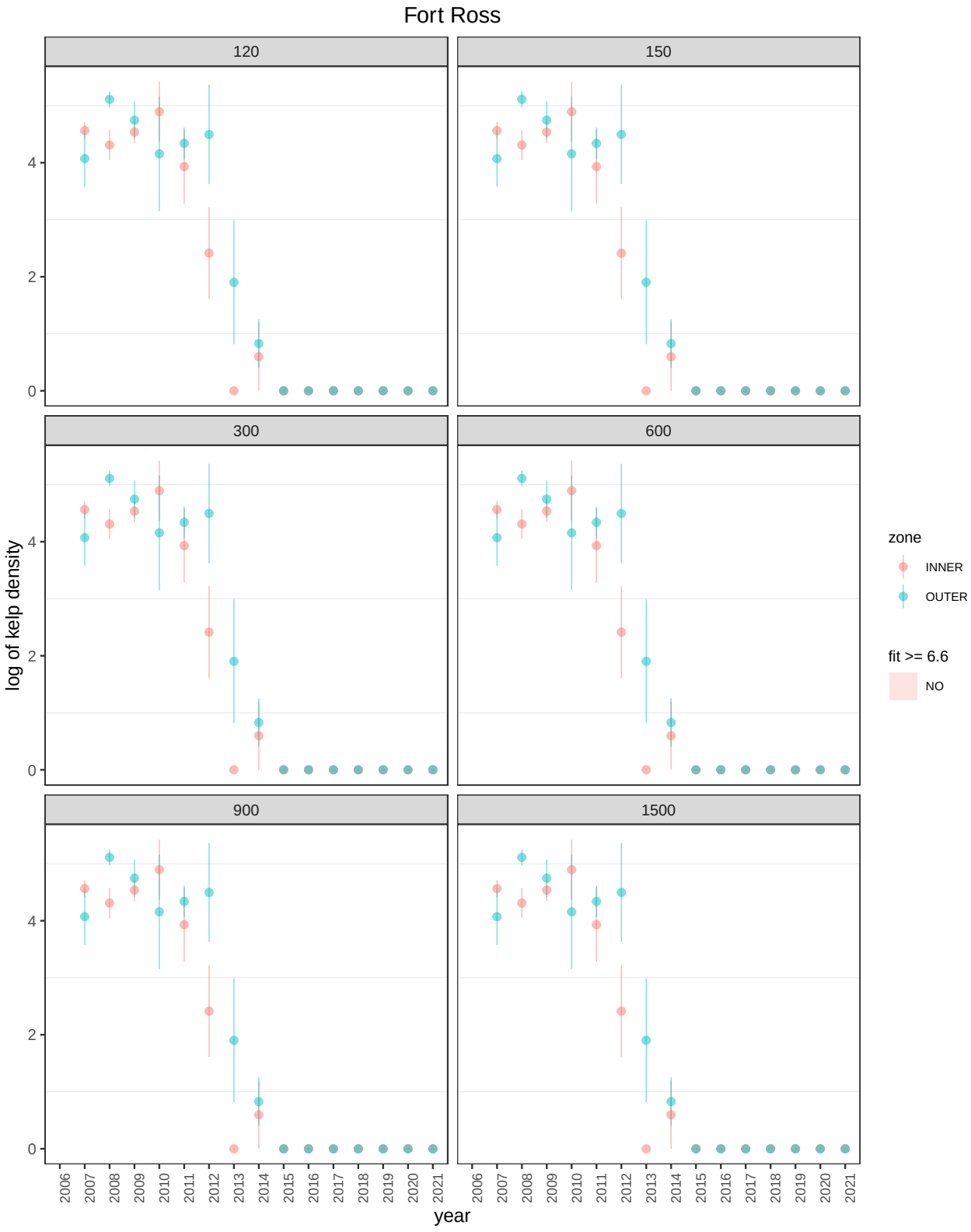
OUTER
fit >= 6.6
NO


Flat Iron Rock
120
150
300
600
900
1500
log of kelp density
0
1
2
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO


Fort Ross
120
150
300
600
900
1500
log of kelp density
0
2
4
2006
2007
2008
2009
2010
2011
2012
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2015
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2018
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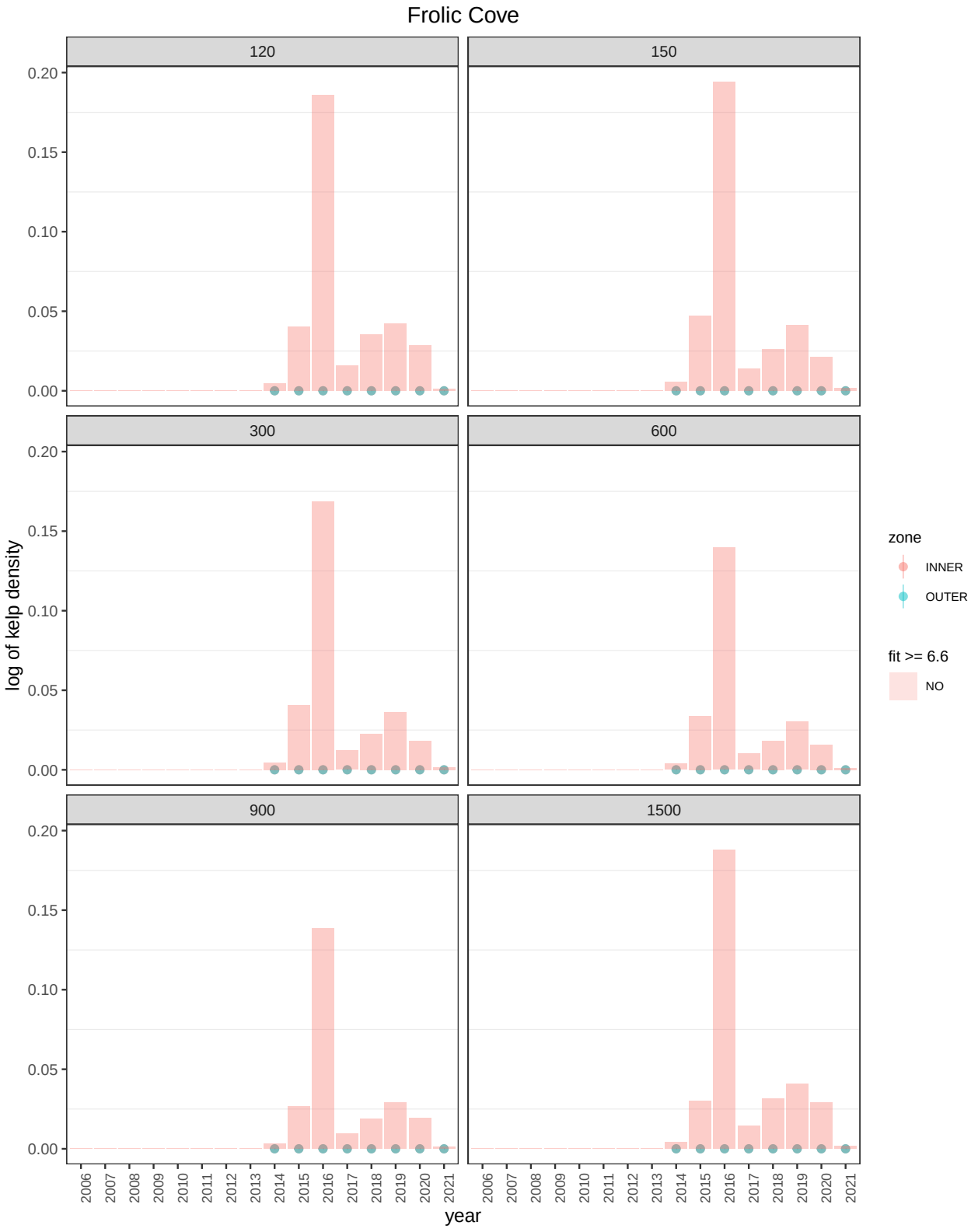
2021
year
zone
INNER
OUTER
fit >= 6.6
NO


Frolic Cove
120
150
300
600
900
1500
log of kelp density
0.20
0.15
0.10
0.05
0.00
2006
2007
2008
2009
2010
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2015
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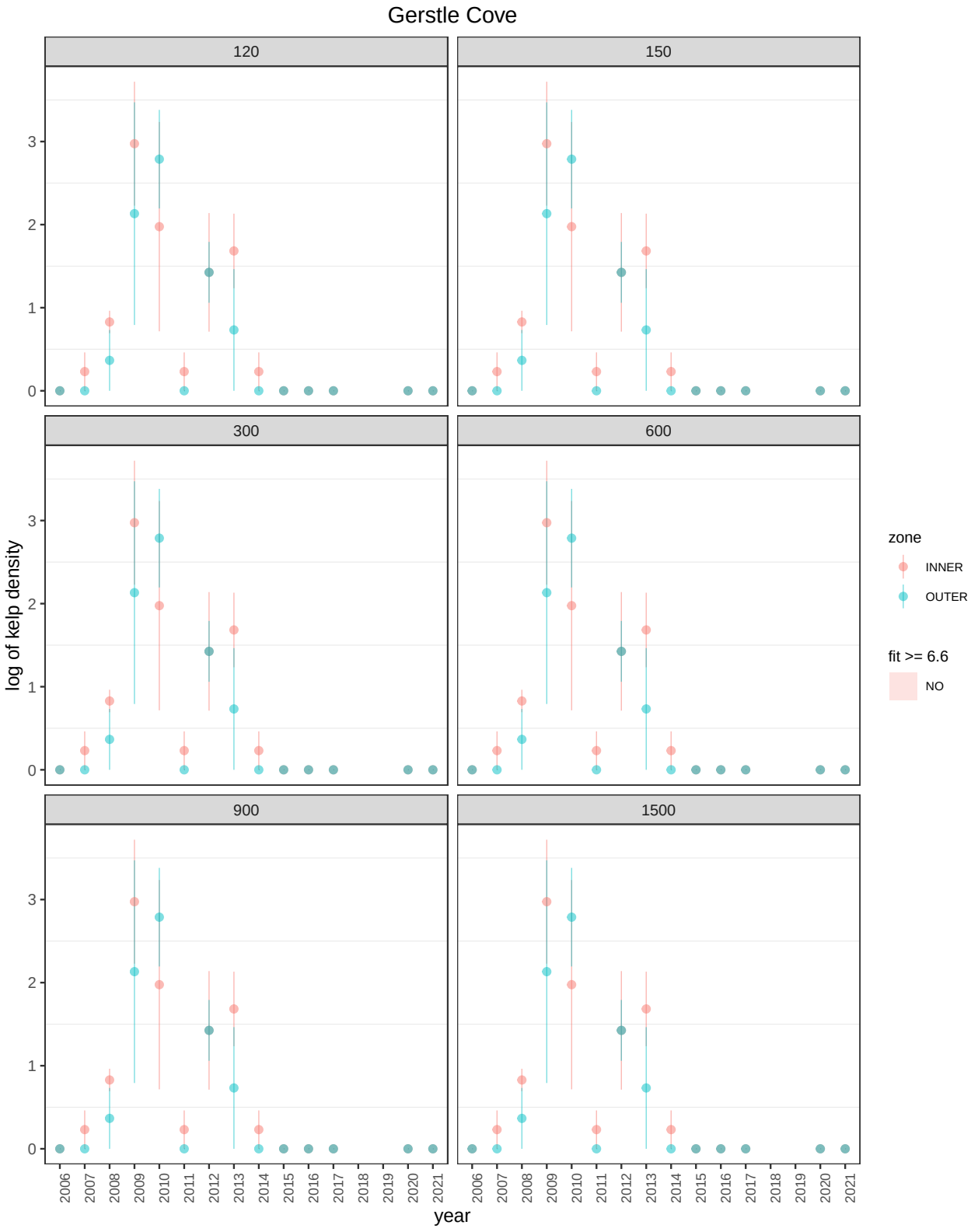
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO


Gerstle Cove
120
150
300
600
900
1500
log of kelp density
0
1
2
3
2006
2007
2008
2009
2010
2011
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2015
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2018
2019
2020
2021
year
zone
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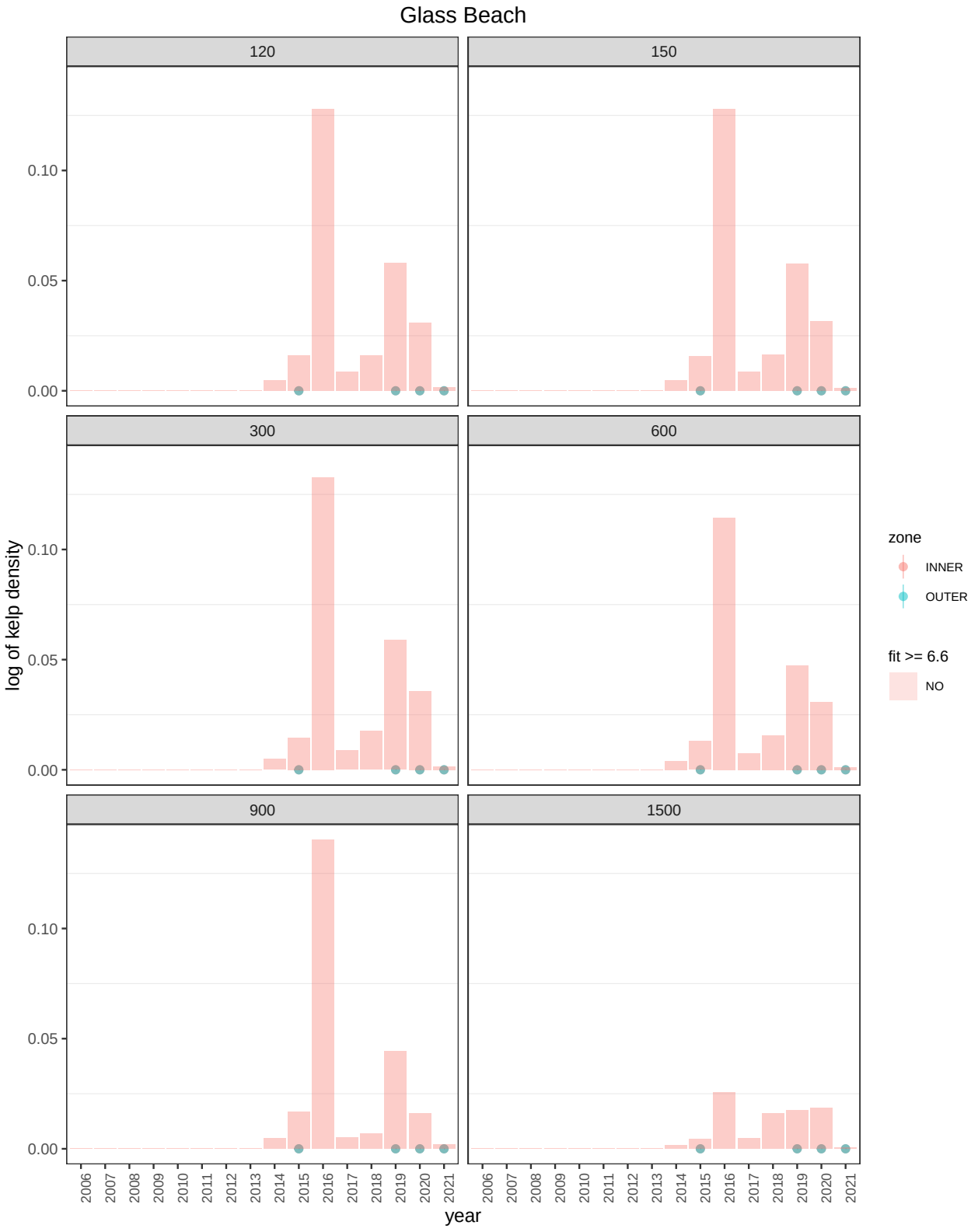
OUTER
fit >= 6.6
NO


Glass Beach
120
150
300
600
900
1500
log of kelp density
0.00
0.05
0.10
2006
2007
2008
2009
2010
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2021
year
zone
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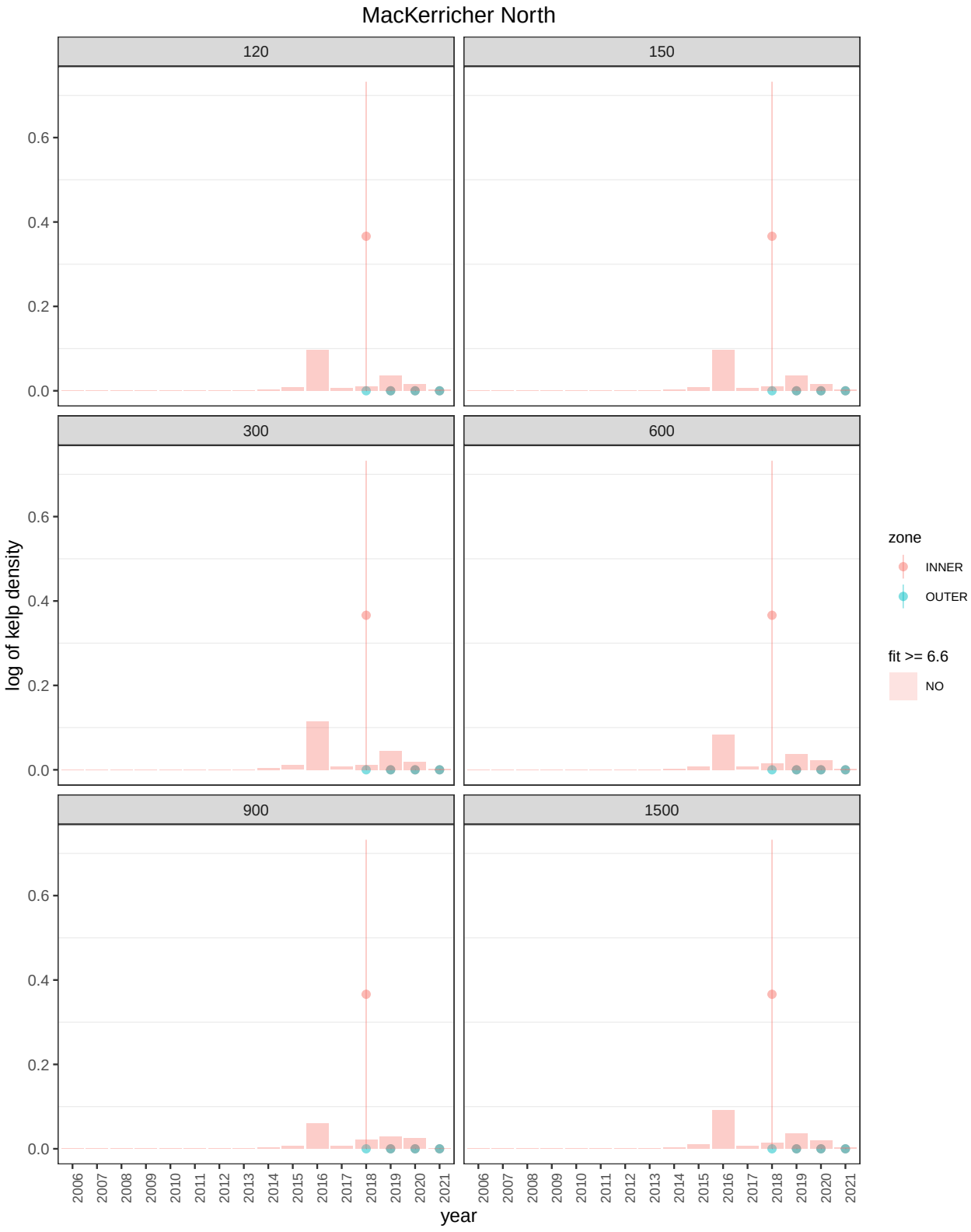
OUTER
fit >= 6.6
NO


MacKerricher North
120
150
300
600
900
1500
log of kelp density
0.0
0.2
0.4
0.6
2006
2007
2008
2009
2010
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2021
year
zone
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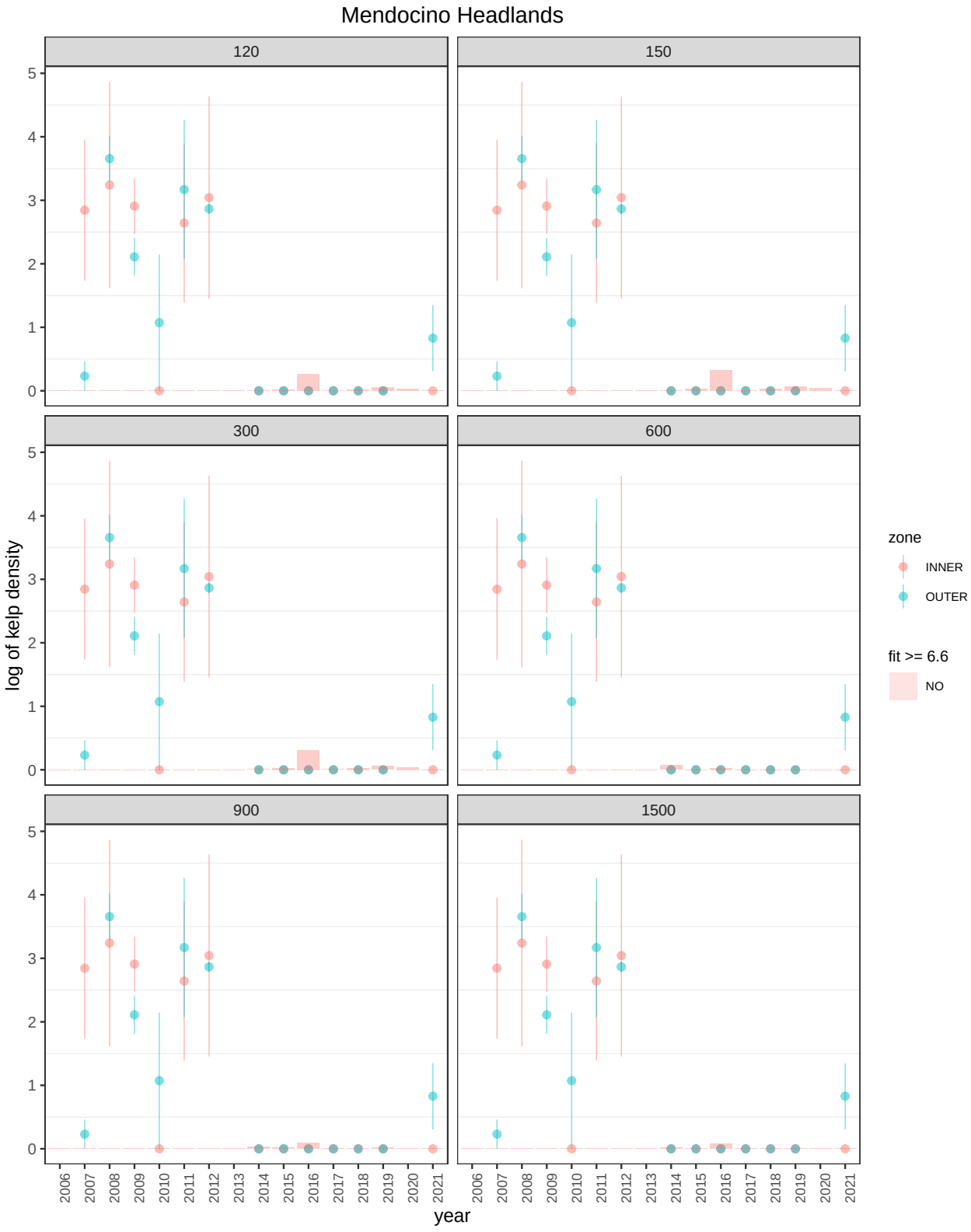
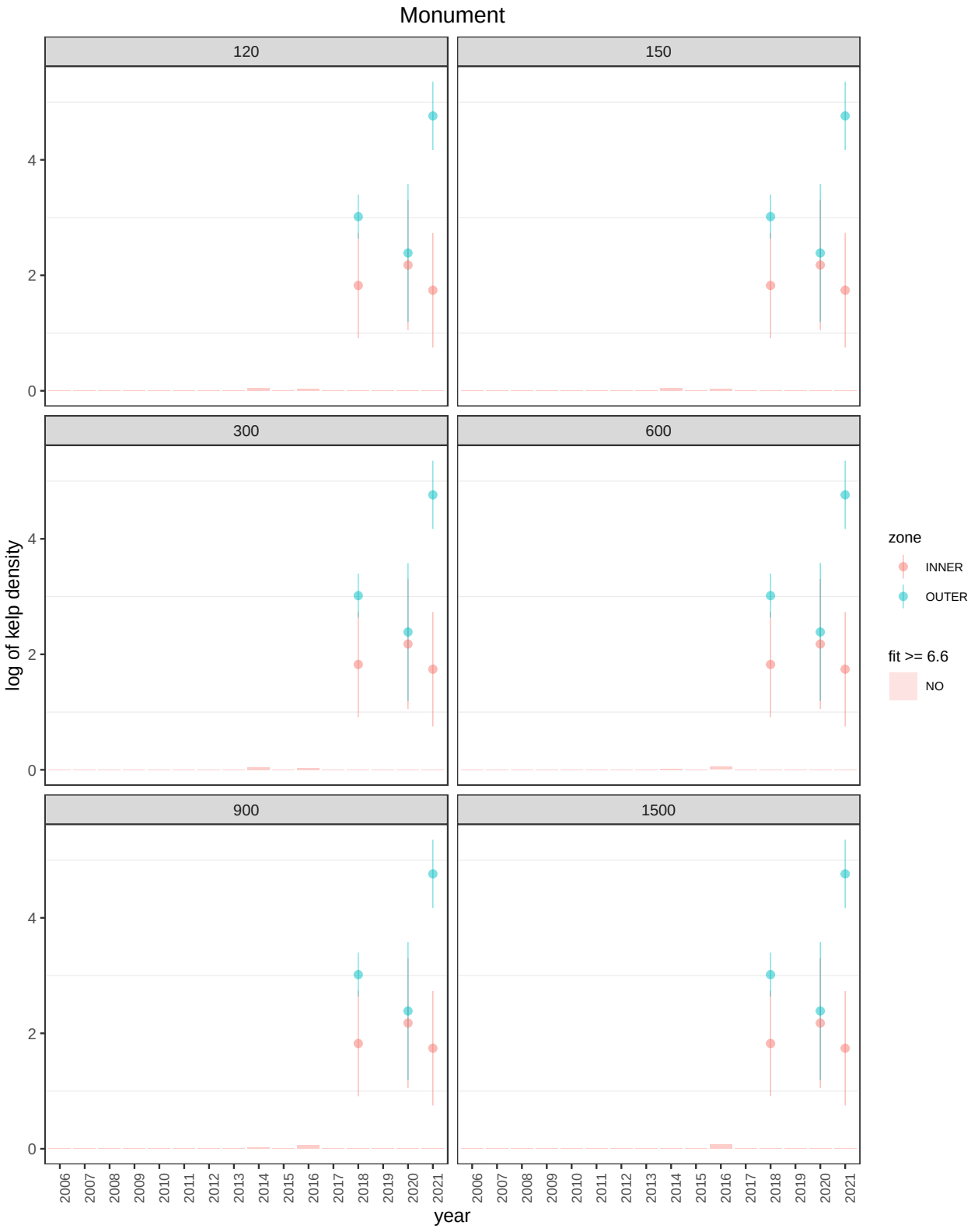
OUTER
fit >= 6.6
NO


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


Monument
120
150
300
600
900
1500
log of kelp density
0
2
4
2006
2007
2008
2009
2010
2011
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2015
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2021
year
zone
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OUTER
fit >= 6.6
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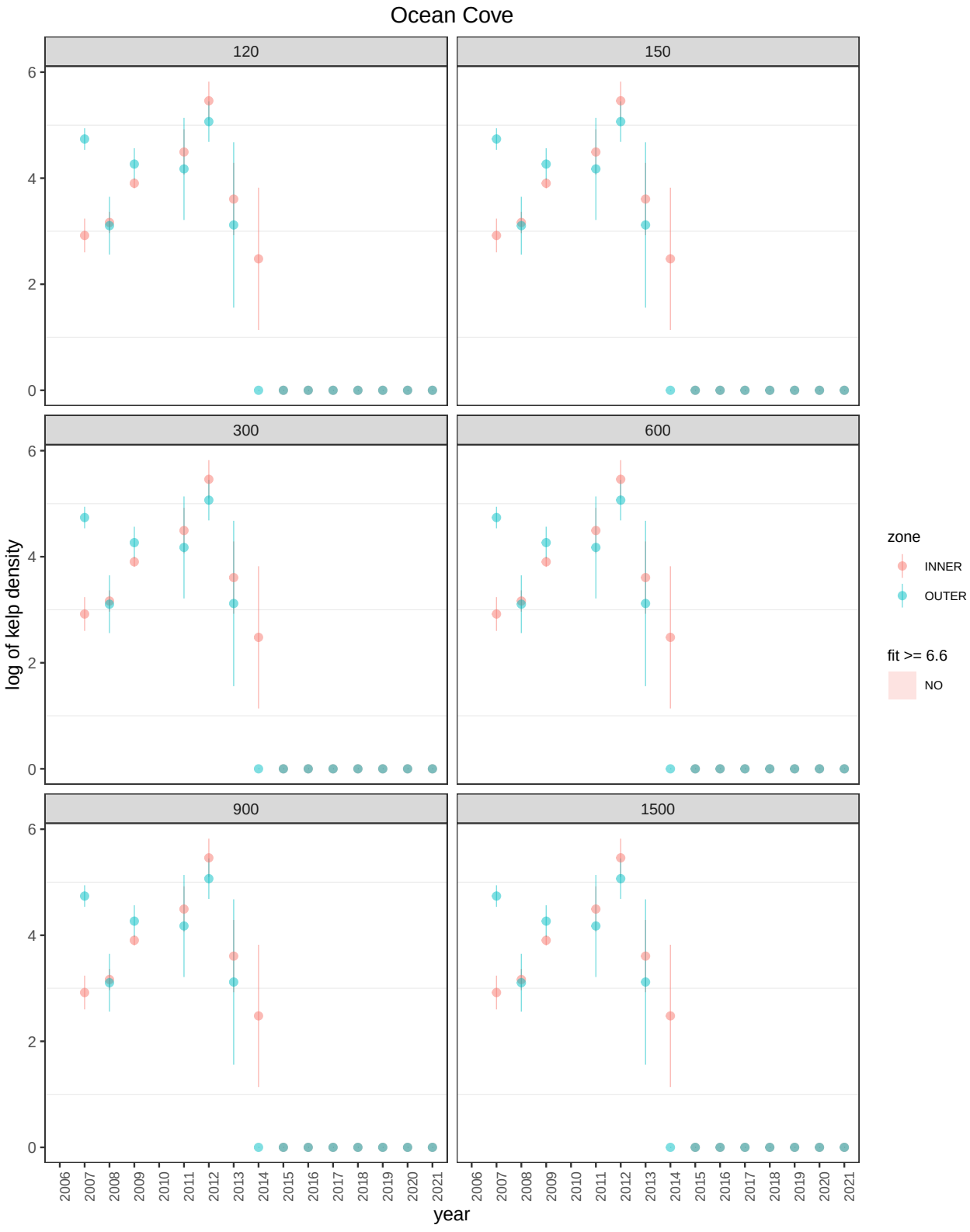
Ocean Cove
120
150
300
600
900
1500
log of kelp density
0
2
4
6
2006
2007
2008
2009
2010
2011
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2015
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2018
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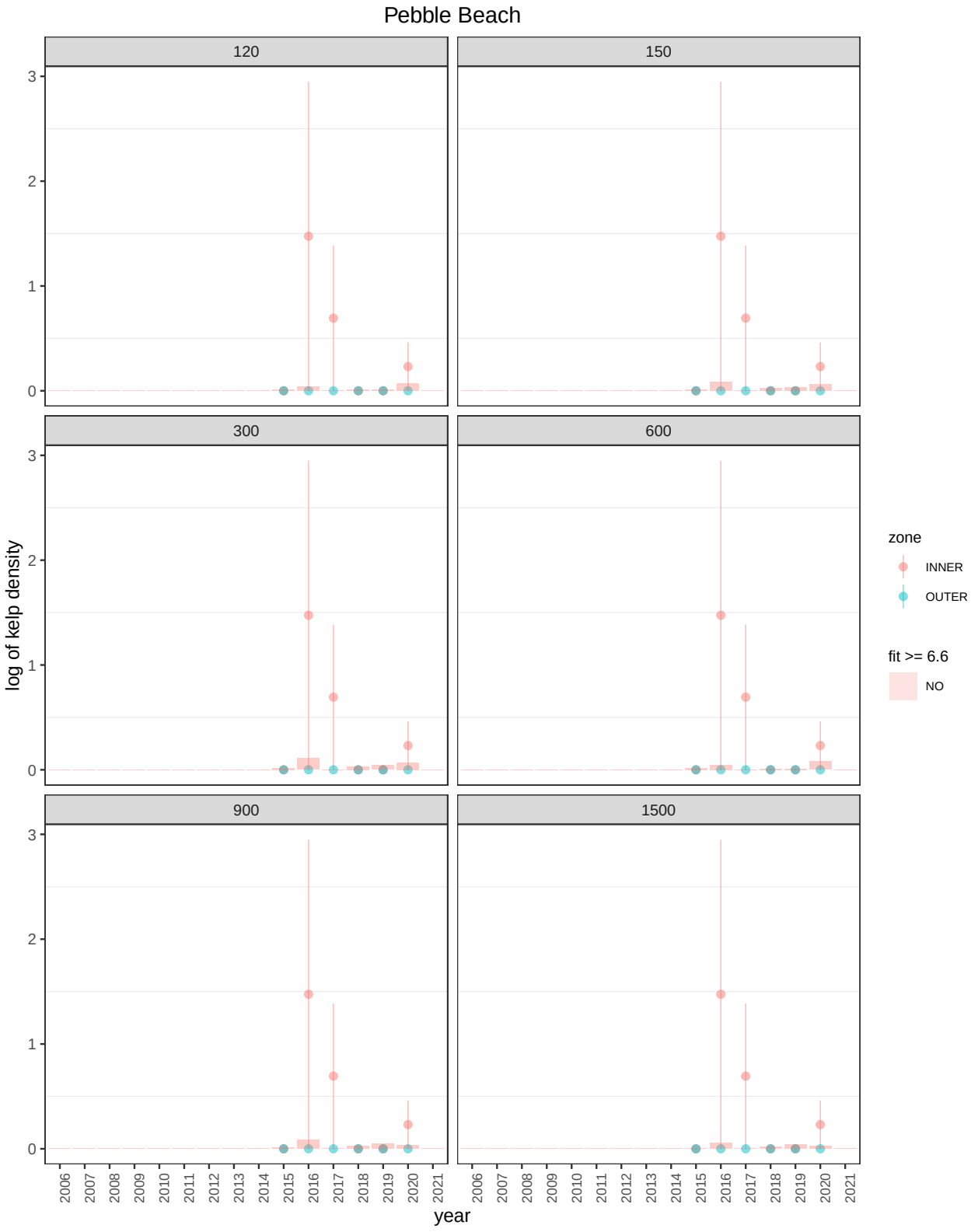
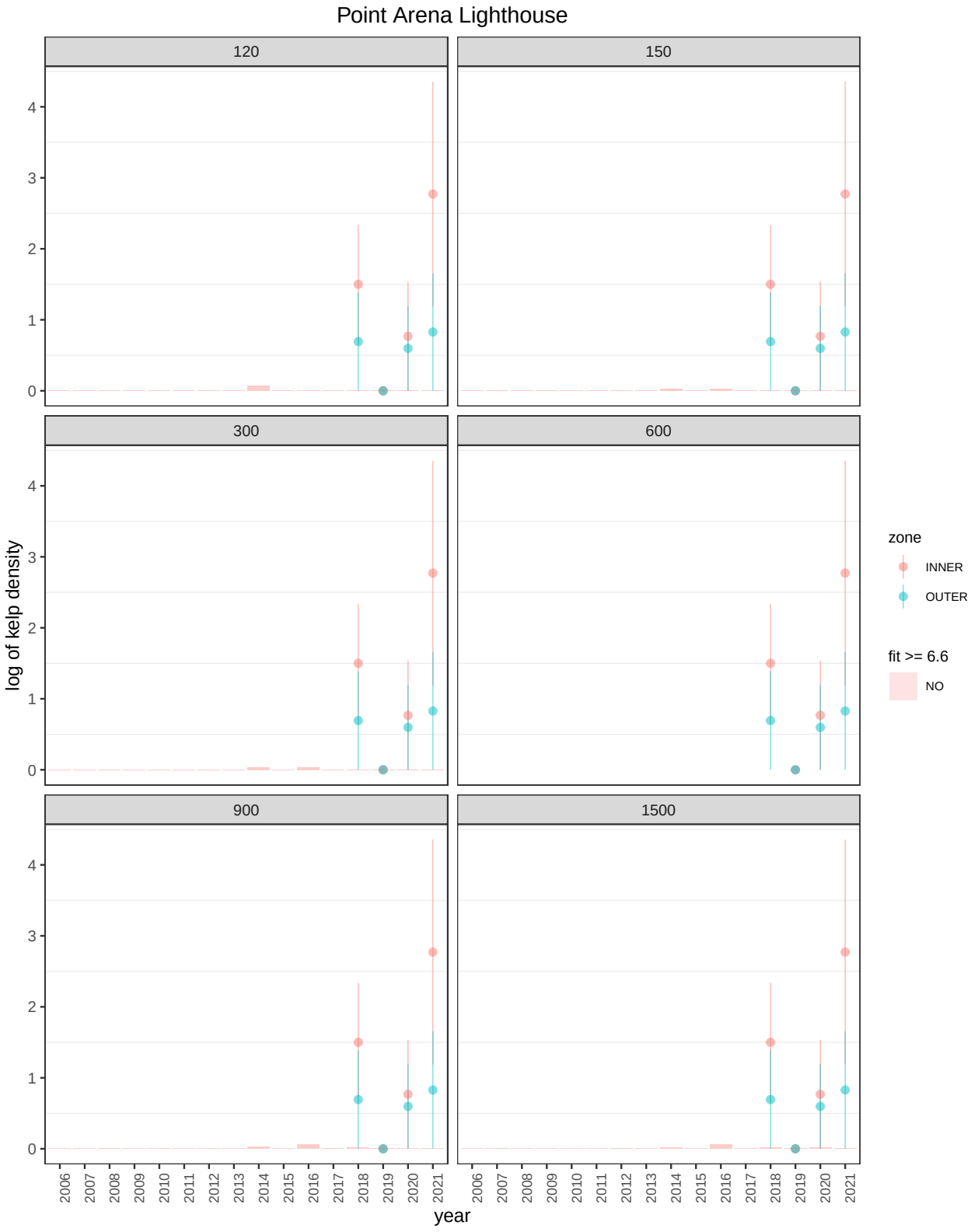
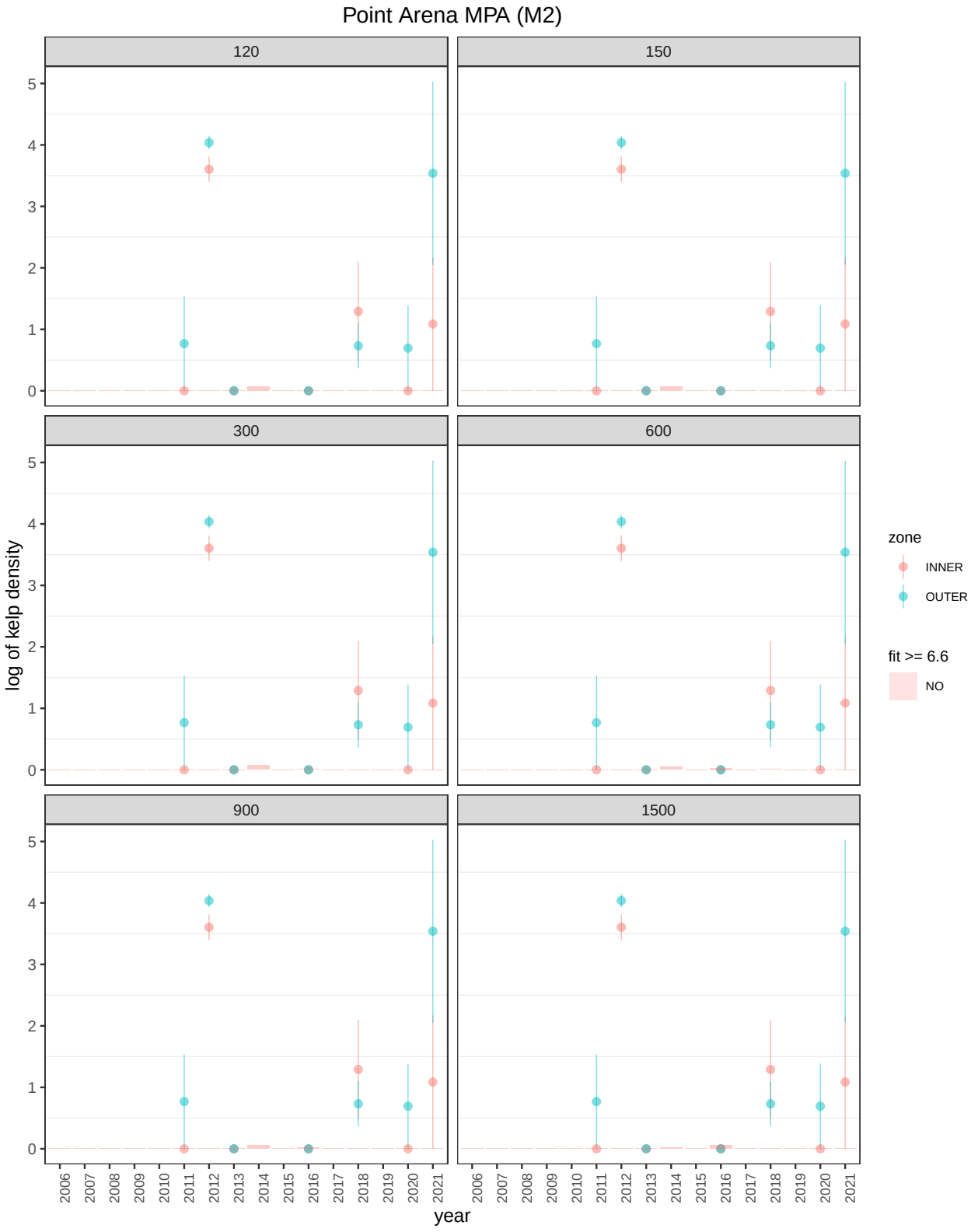
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO


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


Point Arena Lighthouse
120
150
300
600
900
1500
log of kelp density
0
1
2
3
4
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO


Point Arena MPA (M2)
120
150
300
600
900
1500
log of kelp density
0
1
2
3
4
5
2006
2007
2008
2009
2010
2011
2012
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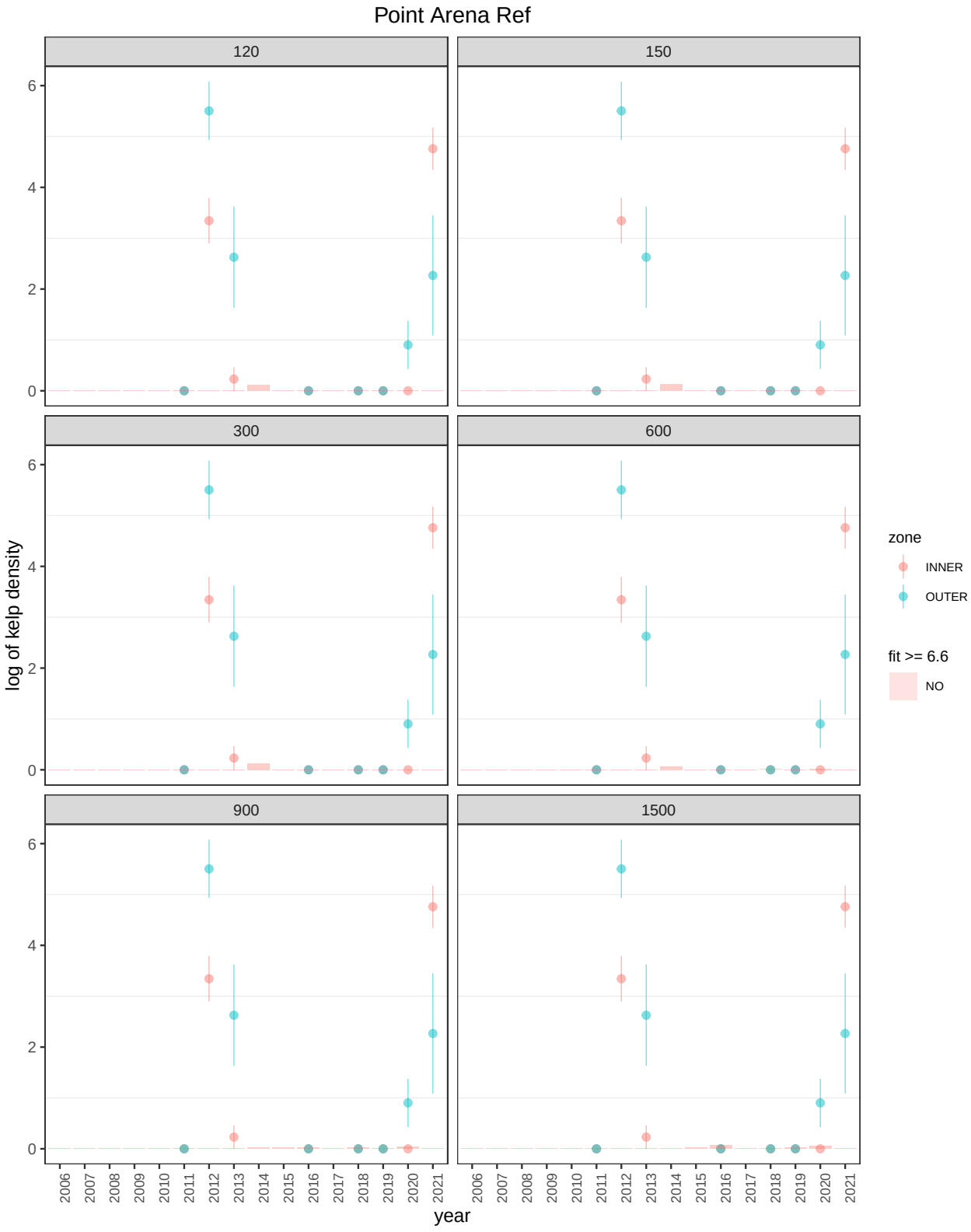
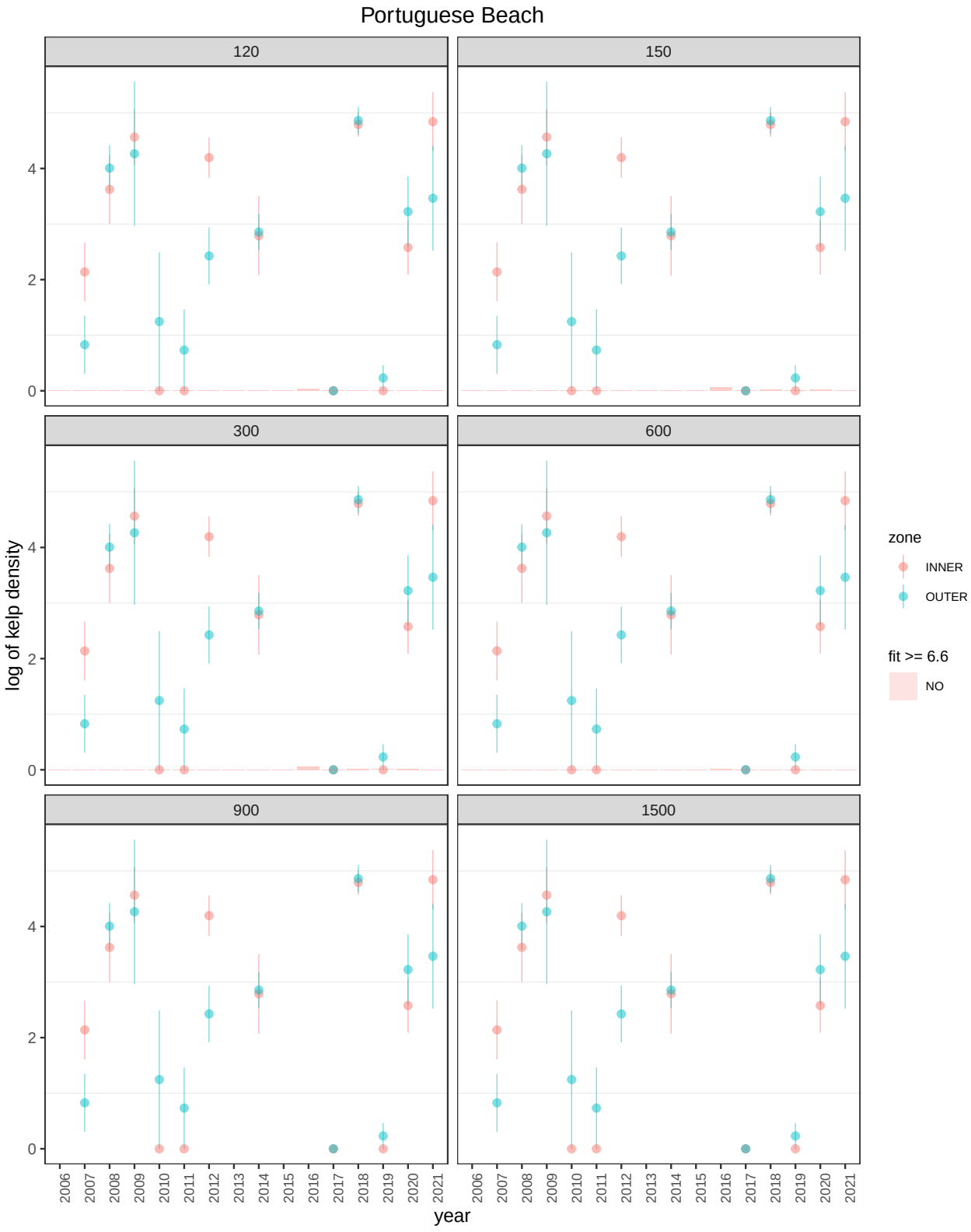
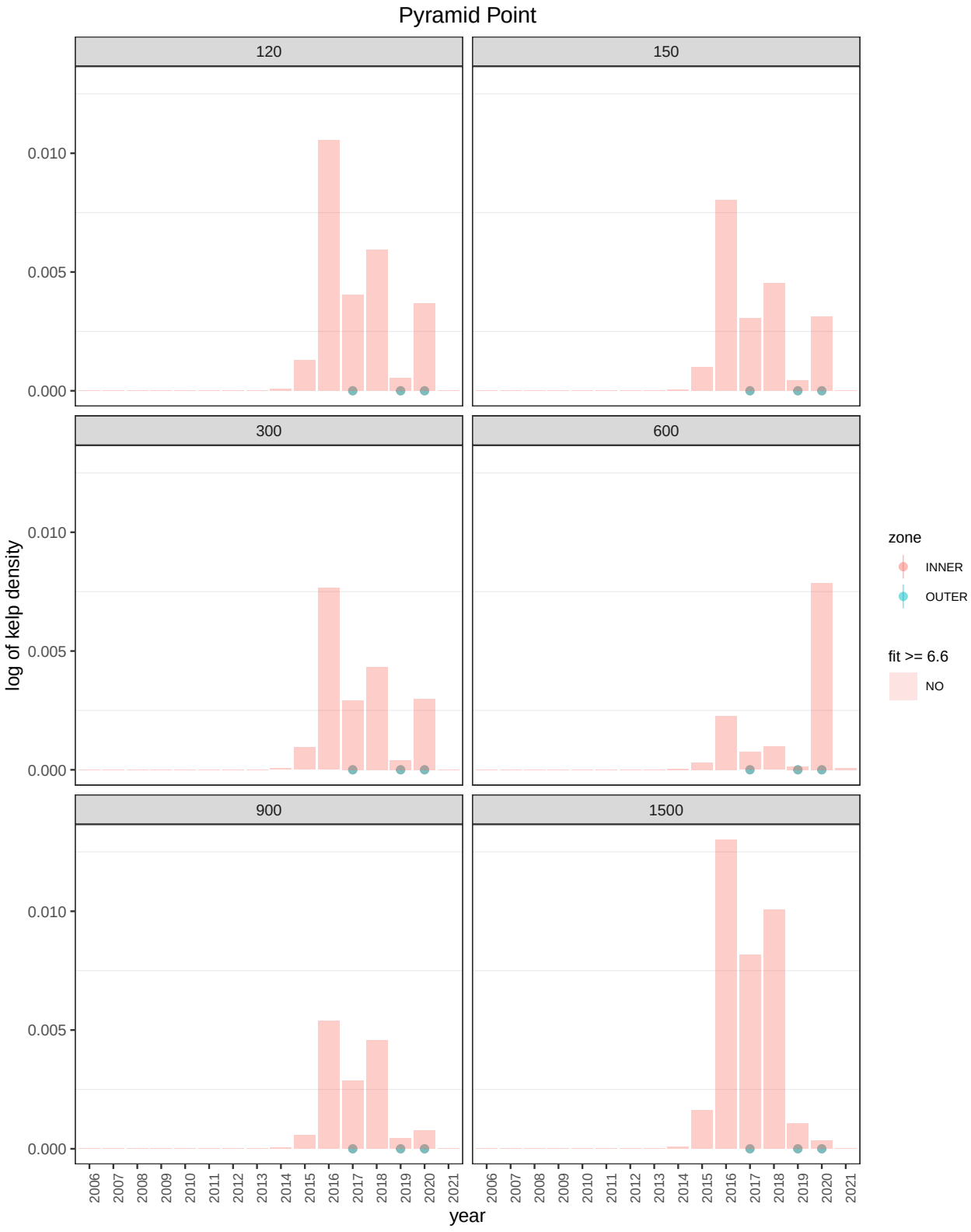
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO


Point Arena Ref
120
150
300
600
900
1500
log of kelp density
0
2
4
6
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO


Portuguese Beach
120
150
300
600
900
1500
log of kelp density
0
2
4
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO


Pyramid Point
120
150
300
600
900
1500
log of kelp density
0.010
0.005
0.000
2006
2007
2008
2009
2010
2011
2012
2013
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2015
2016
2017
2018
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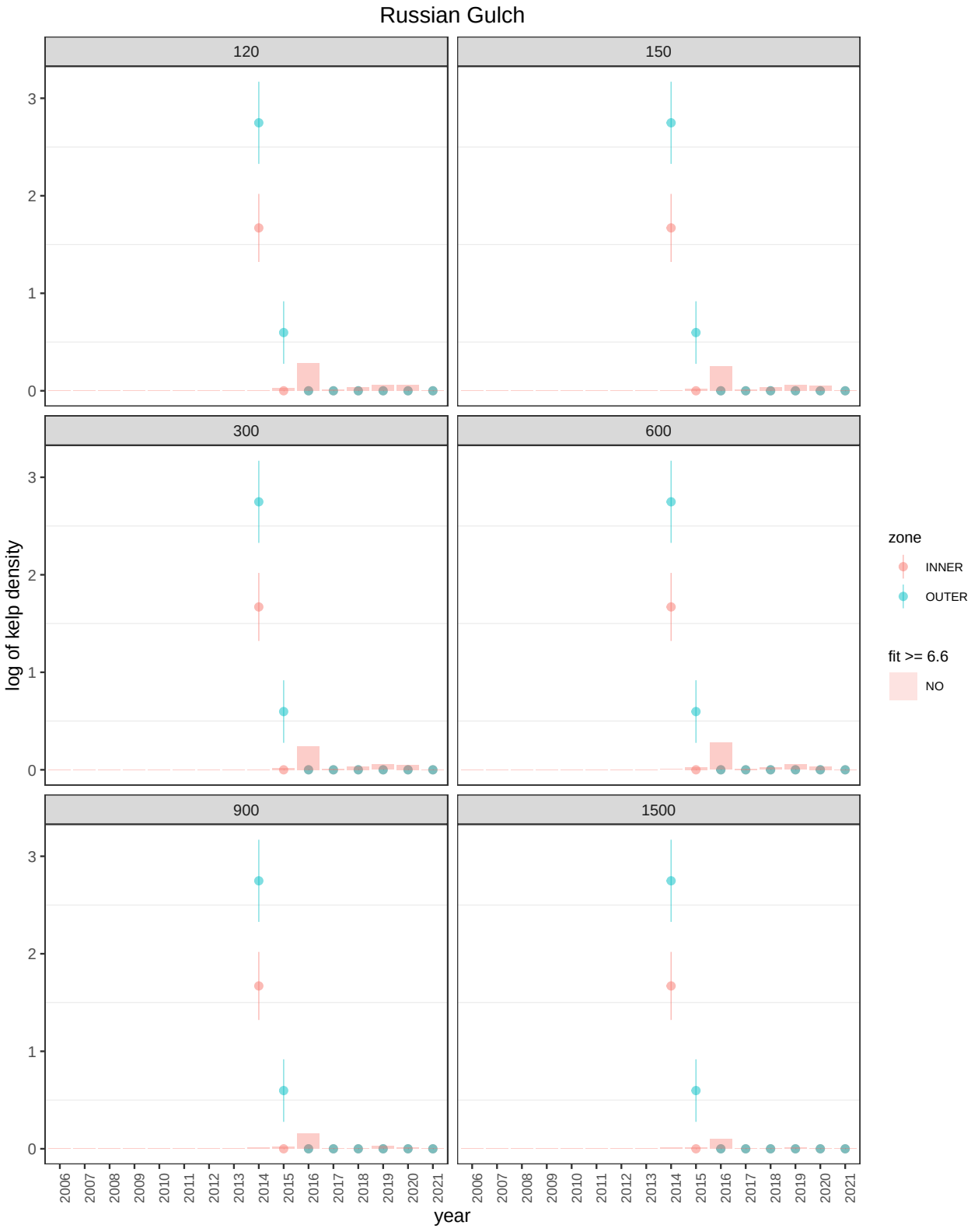
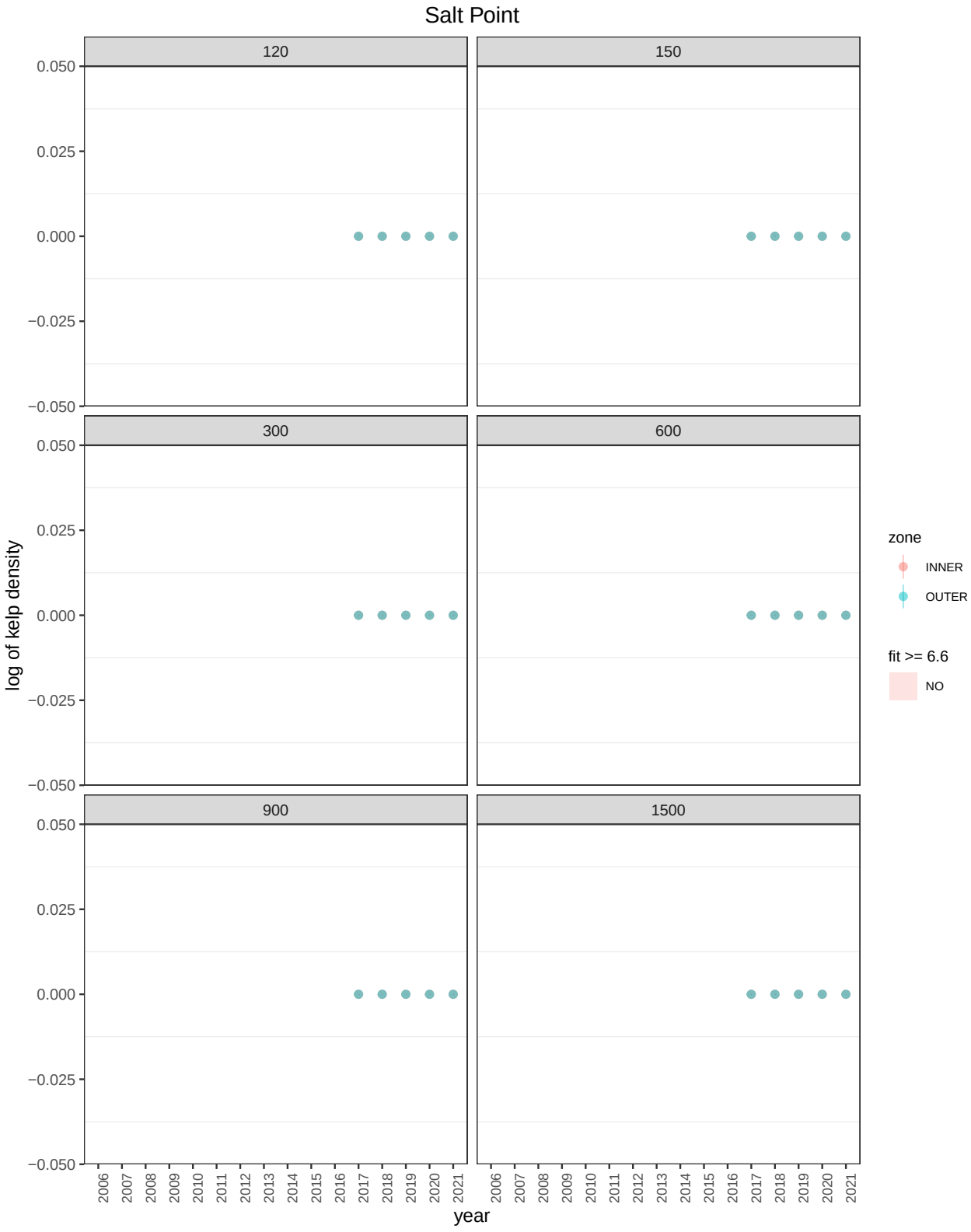
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO


Russian Gulch
120
150
300
600
900
1500
log of kelp density
0
1
2
3
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO


Salt Point
120
150
300
600
900
1500
log of kelp density
0.050
0.025
0.000
−0.025
−0.050
2006
2007
2008
2009
2010
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2015
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2018
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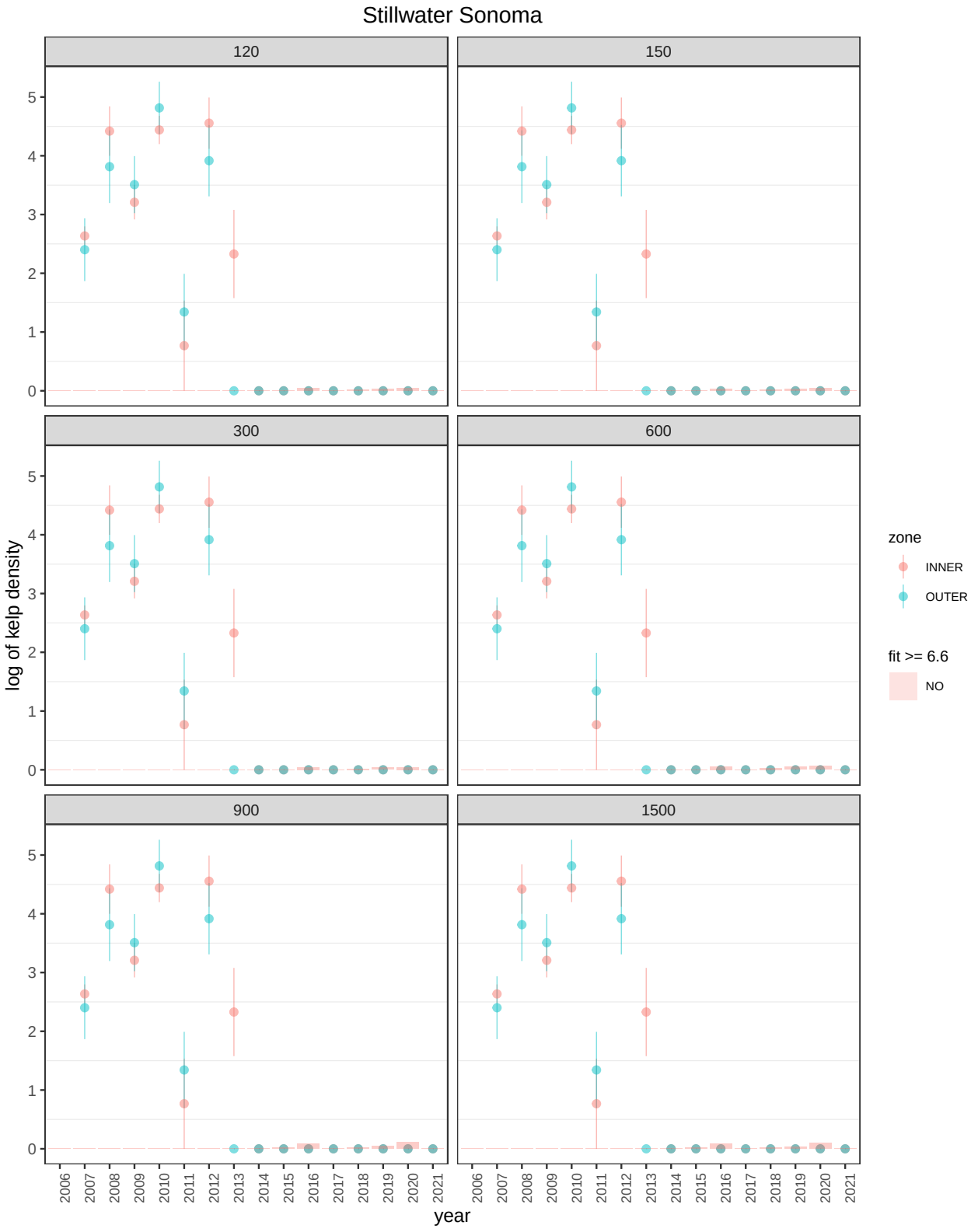
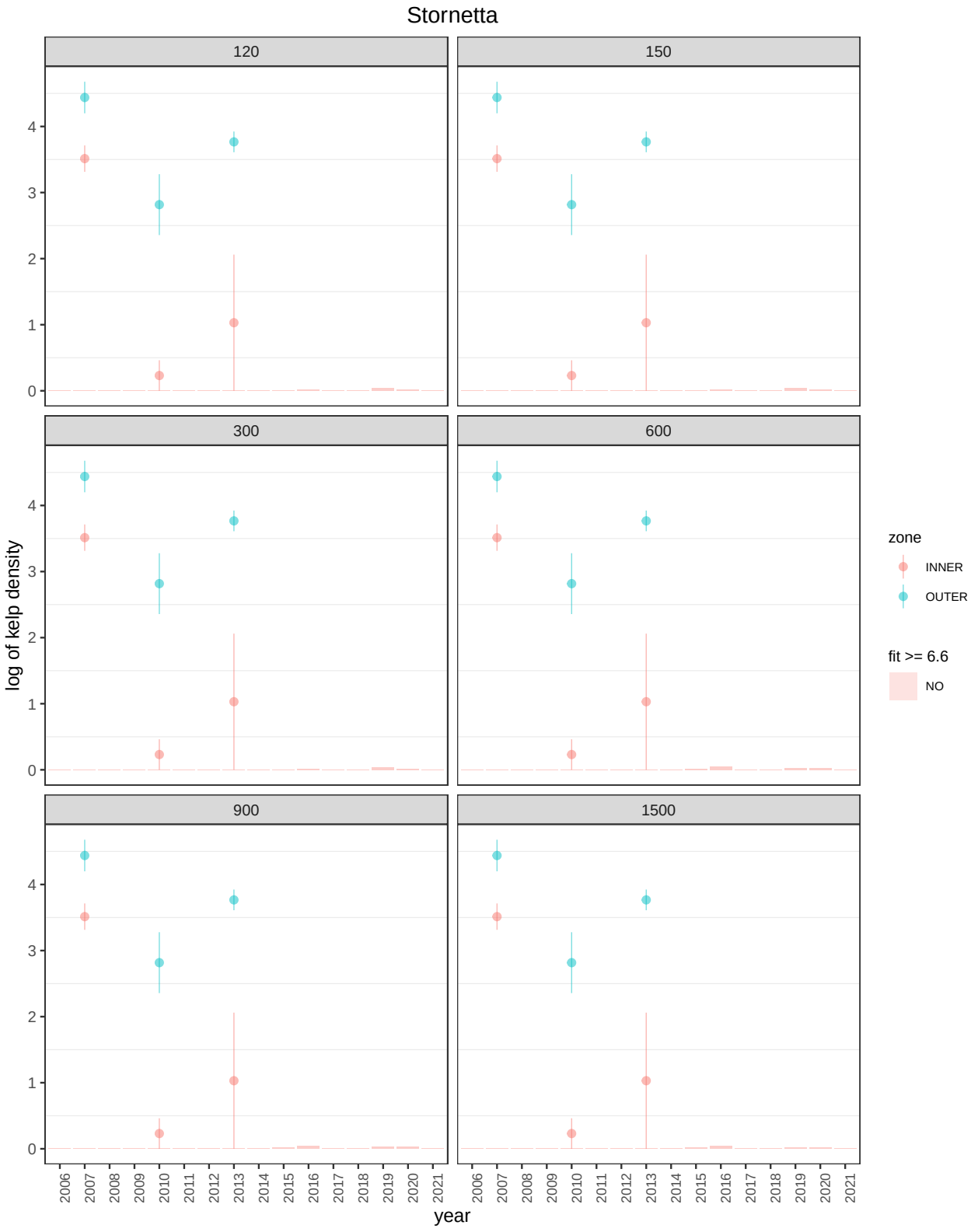
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO


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


Stornetta
120
150
300
600
900
1500
log of kelp density
0
1
2
3
4
2006
2007
2008
2009
2010
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2012
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2015
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2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
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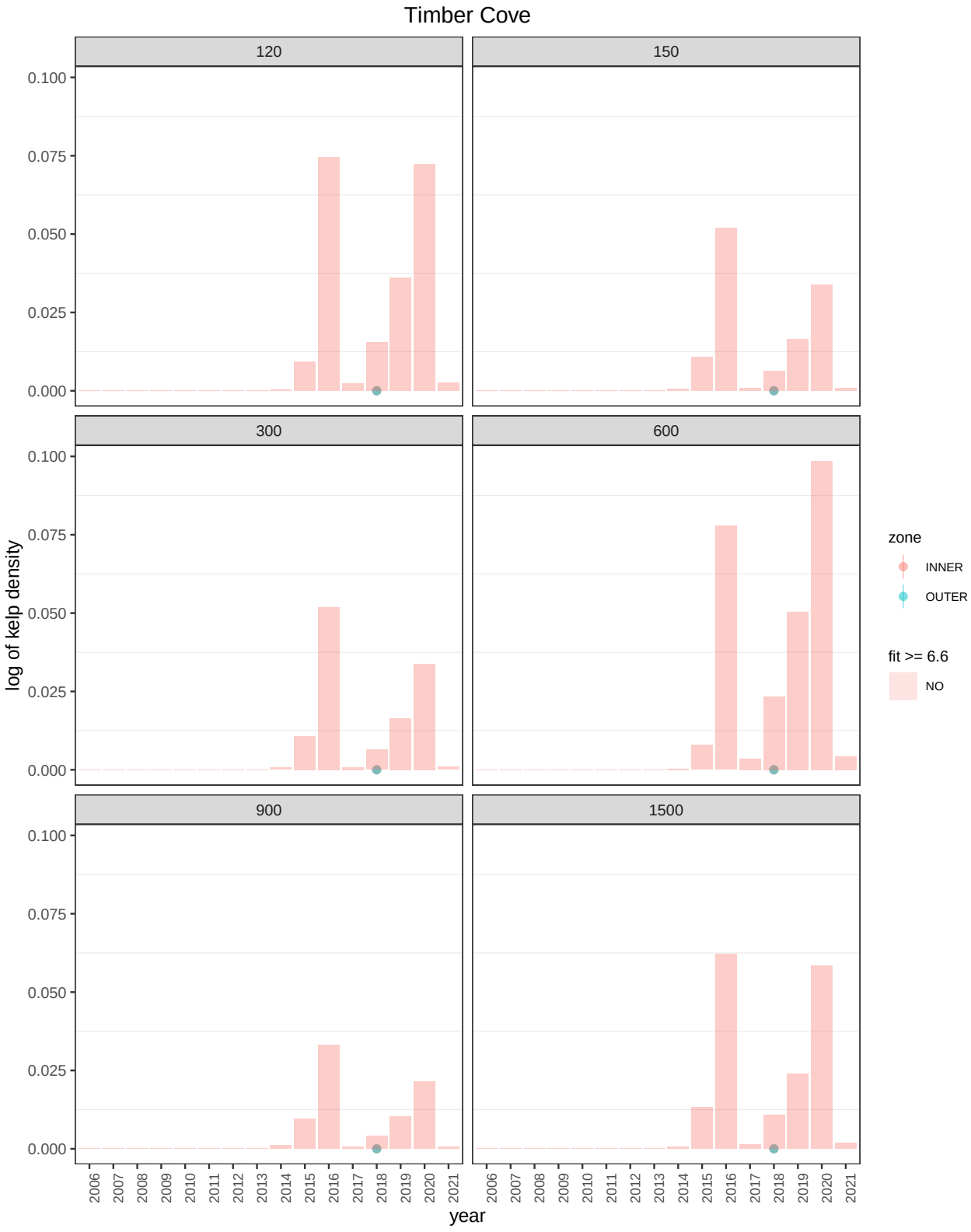
Timber Cove
120
150
300
600
900
1500
0.100
0.075
0.050
0.025
0.000
log of kelp density
2006
2007
2008
2009
2010
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2018
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2020
2021
year
zone
INNER
OUTER
fit >= 6.6
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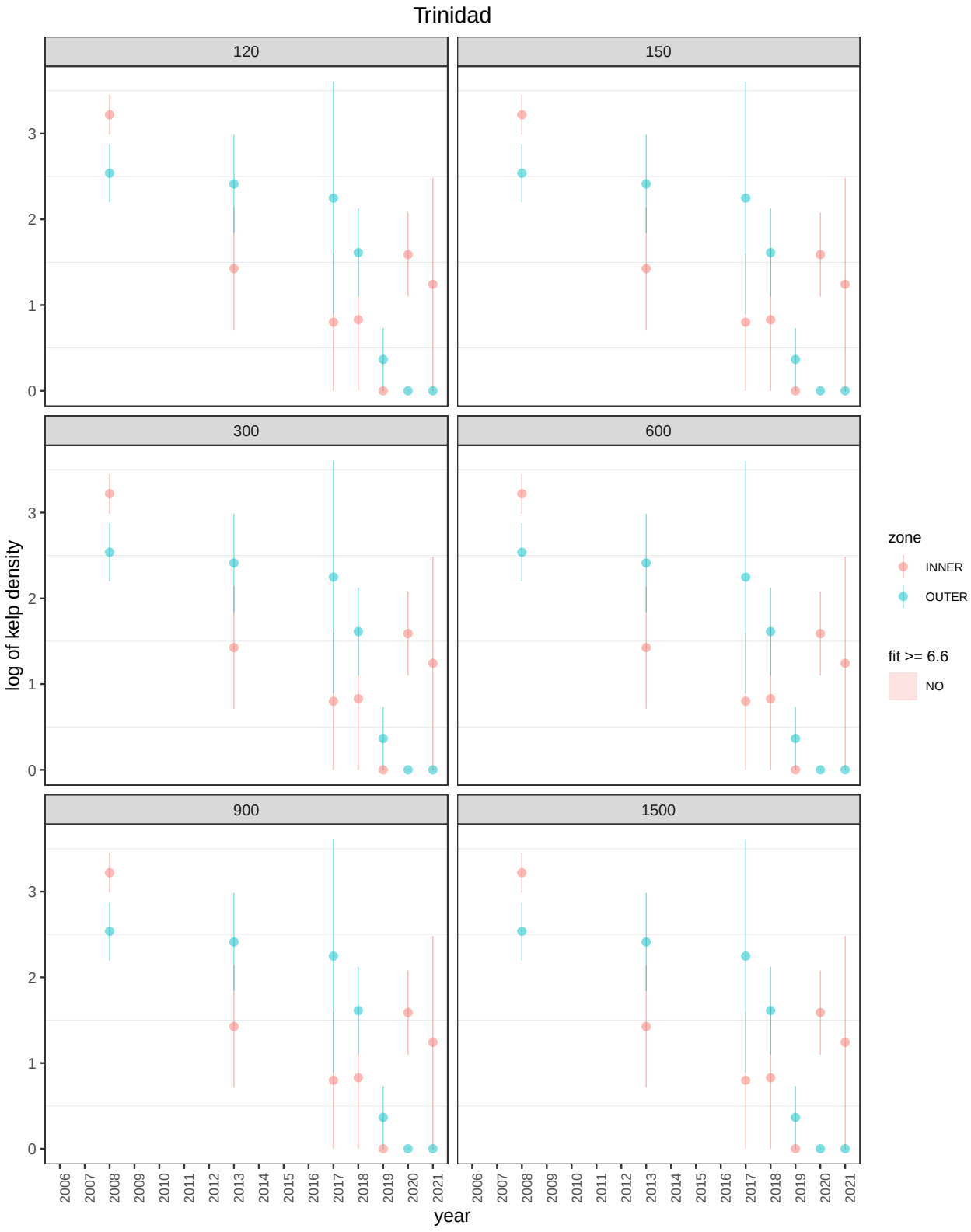
Trinidad
120
150
300
600
900
1500
log of kelp density
0
1
2
3
2006
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2008
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2010
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2020
2021
year
zone
INNER
OUTER
fit >= 6.6
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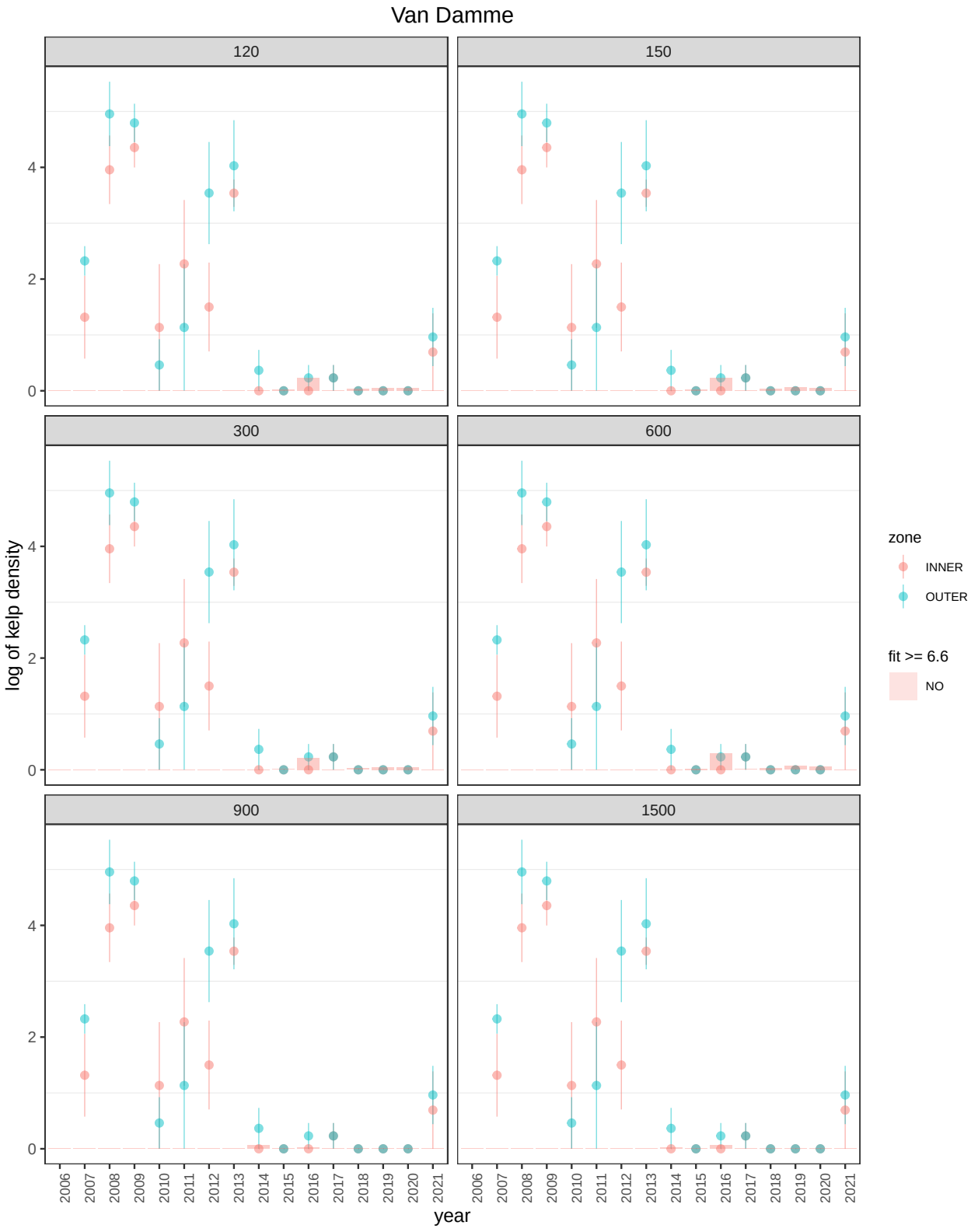
Van Damme
120
150
300
600
900
1500
log of kelp density
0
2
4
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
year
zone
INNER
OUTER
fit >= 6.6
NO