Catch probability

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```
library(tidyverse)
library(rjson)
library(baseballr)
library(rvest)
```

Scrape data

We scrape individual play data for every fly ball hit to an outfielder during the 2024 season. This chunk only needs to be run once.

```
scrape_of_catch_prob_data <- function(year) {
  # Load in player IDs
  playerIDs <- read_csv(paste0("../data/of_playerIDs_", year, ".csv")) %>%
               select(player_id)

  # Scrape play-by-play data
  data <- lapply(1:nrow(playerIDs),
              function(j) {
                # Scrape data
                rawdata <- fromJSON(
                  file = paste0("https://baseballsavant.mlb.com/player-services/range?playerId=",
                                playerIDs[j,], "&season=", year, "&playerType=fielder"), simplify = TRUE
                )

                # If the URL exists:
                if (length(rawdata) > 0) {

                  # Change any null columns (e.g., sprint_speed) to NA
                  for (k in 1:length(rawdata)) {
                    rawdata[[k]][sapply(rawdata[[k]], is.null)] <- NA
                  }

                  # Convert raw data to tibble
                  tibble(data.frame(matrix(unlist(rawdata),
                                           nrow = length(rawdata),
                                           byrow = TRUE,
                                           dimnames = list(1:length(rawdata),
                                                           names(rawdata[[1]])))))) %>%
                    mutate(across(c(game_pk:name_display_first_last, pos),
                                  as.factor),
```

```
                          across(c(stars:distance, hang_time, out:sprint_speed),
                                 as.numeric))
                }
              }
            )

  return(tibble(do.call(rbind.data.frame, data)))
}
```

```
clean_of_catch_prob_data <- function(year) {
  of_catch_prob <- read_csv(paste0("../data/of_catch_prob_", year, "_orig.csv")) %>%
                          filter(!is.na(sprint_speed)) %>%
                          mutate(game_pk = as.factor(game_pk),
                                 play_id = as.factor(play_id),
                                 player = as.factor(name_display_first_last),
                                 pos = as.factor(pos))

  teams <- fg_batter_leaders(startseason = year, endseason = year) %>%
              mutate(team_name = as.factor(ifelse(team_name == "- - -", "MUL", team_name))) %>%
              select(player = PlayerName, team = team_name)
  of_catch_prob_teams <- teams %>% right_join(of_catch_prob, by = "player")

  stadiums <- mlb_schedule(season = year) %>%
                mutate(game_pk = as.factor(game_pk),
                       stadium = as.factor(venue_name)) %>%
                select(game_pk, stadium)
  of_catch_prob_teams_stadiums <- of_catch_prob_teams %>%
                                    left_join(stadiums, by = "game_pk")

  dimensions_table <- read_html("http://www.andrewclem.com/Baseball/Stadium_statistics.html") %>%
                        html_elements("table") %>%
                        html_table()
  dimensions_colnames <- dimensions_table[[1]] %>% janitor::row_to_names(row_number=1) %>%
                          select(stadium = "Stadium (see notes)",
                                 wall_height_lf = "LF", wall_height_cf = "CF", wall_height_rf = "RF",
                                 dist_lf = "Left field", dist_lc = "Left-center", dist_cf = "Center fiel
                                 dist_rc = "Right-center", dist_rf = "Right field") %>%
                          colnames()
  dimensions_data <- dimensions_table[[2]] %>%
                        select(X1, X12, X13, X14, X17, X18, X19, X20, X21) %>%
                        rename_with(~dimensions_colnames) %>%
                        mutate(stadium = as.factor(stadium)) %>%
                        mutate(stadium = str_remove_all(stadium, " \\*")) %>%
                        mutate(across(contains("wall"),
                                      function(col) {str_remove_all(col, "[()\\[\\]]")})) %>%
                        mutate(across(contains("wall"), as.numeric)) %>%
                        mutate(across(contains("dist"),
                                      function(col) {str_remove_all(col, "[()\\[\\]]")})) %>%
                        mutate(across(contains("dist"), as.numeric)) %>%
                        mutate(stadium = fct_recode(stadium,
                                                    "Old Yankee Stadium" = "Yankee Stadium",
                                                    "Yankee Stadium" = "Yankee Stadium II",
                                                    "American Family Field" = "Miller Park",
```

```
                                                    "Busch Stadium" = "Busch Stadium III",
                                                    "Great American Ball Park" = "Great American Ballpa
                                                    "loanDepot park" = "Marlins Park",
                                                    "Petco Park" = "PETCO Park",
                                                    "T-Mobile Park" = "Safeco Field",
                                                    "Truist Park" = "Truist (ex-SunTrust) Park"))
  of_catch_prob_teams_stadiums_dims <- of_catch_prob_teams_stadiums %>%
                                       left_join(dimensions_data, by = "stadium")

  return(of_catch_prob_teams_stadiums_dims)
}
```

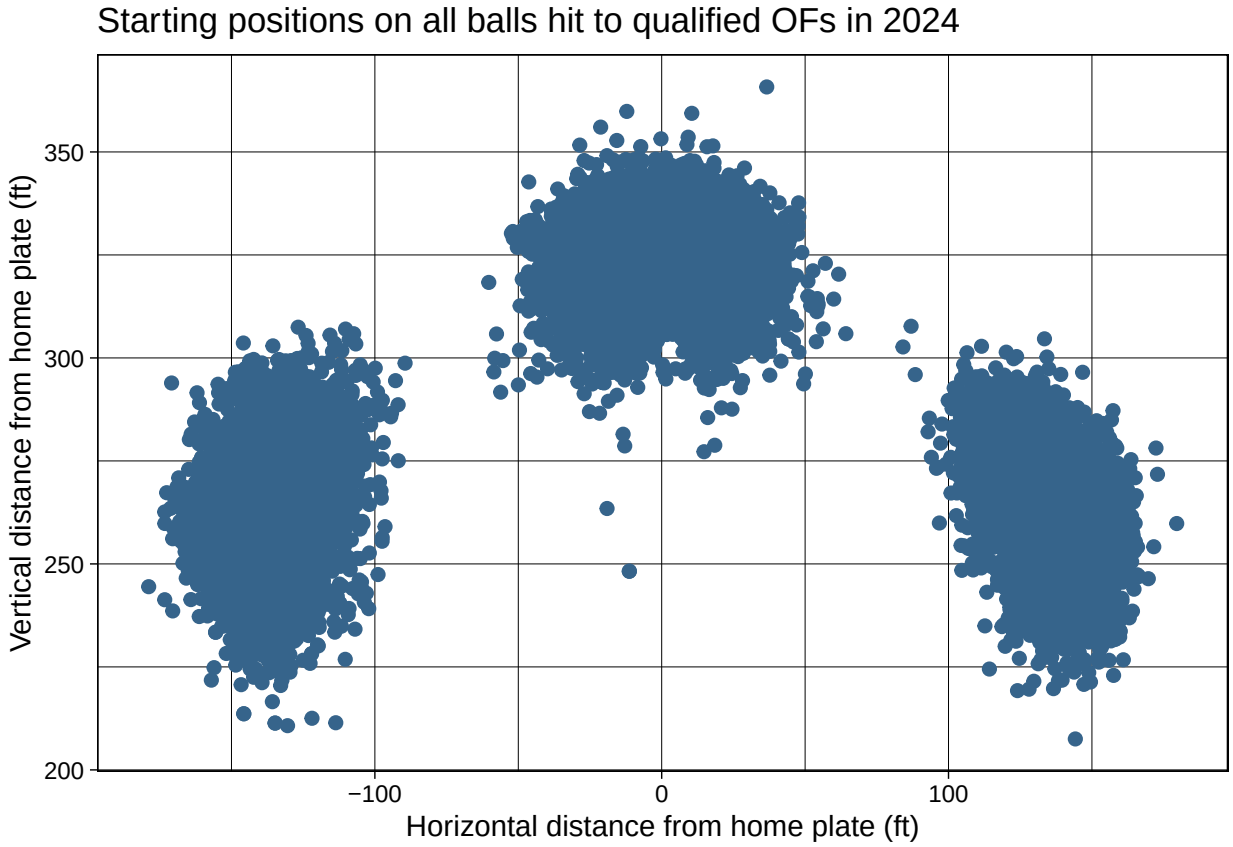
```
of_catch_prob_2024_orig <- scrape_of_catch_prob_data("2024")
of_catch_prob_2024_orig %>% write_csv("../data/of_catch_prob_2024_orig.csv")
of_catch_prob_2024 <- clean_of_catch_prob_data("2024")
of_catch_prob_2024 %>% write_csv("../data/of_catch_prob_2024.csv")

of_catch_prob_2023_orig <- scrape_of_catch_prob_data("2023")
of_catch_prob_2023_orig %>% write_csv("../data/of_catch_prob_2023_orig.csv")
of_catch_prob_2023 <- clean_of_catch_prob_data("2023")
of_catch_prob_2023 %>% write_csv("../data/of_catch_prob_2023.csv")
```

Load in data

```
of_catch_prob_2024 <- read_csv("../data/of_catch_prob_2024.csv")
of_catch_prob_2023 <- read_csv("../data/of_catch_prob_2023.csv")
```

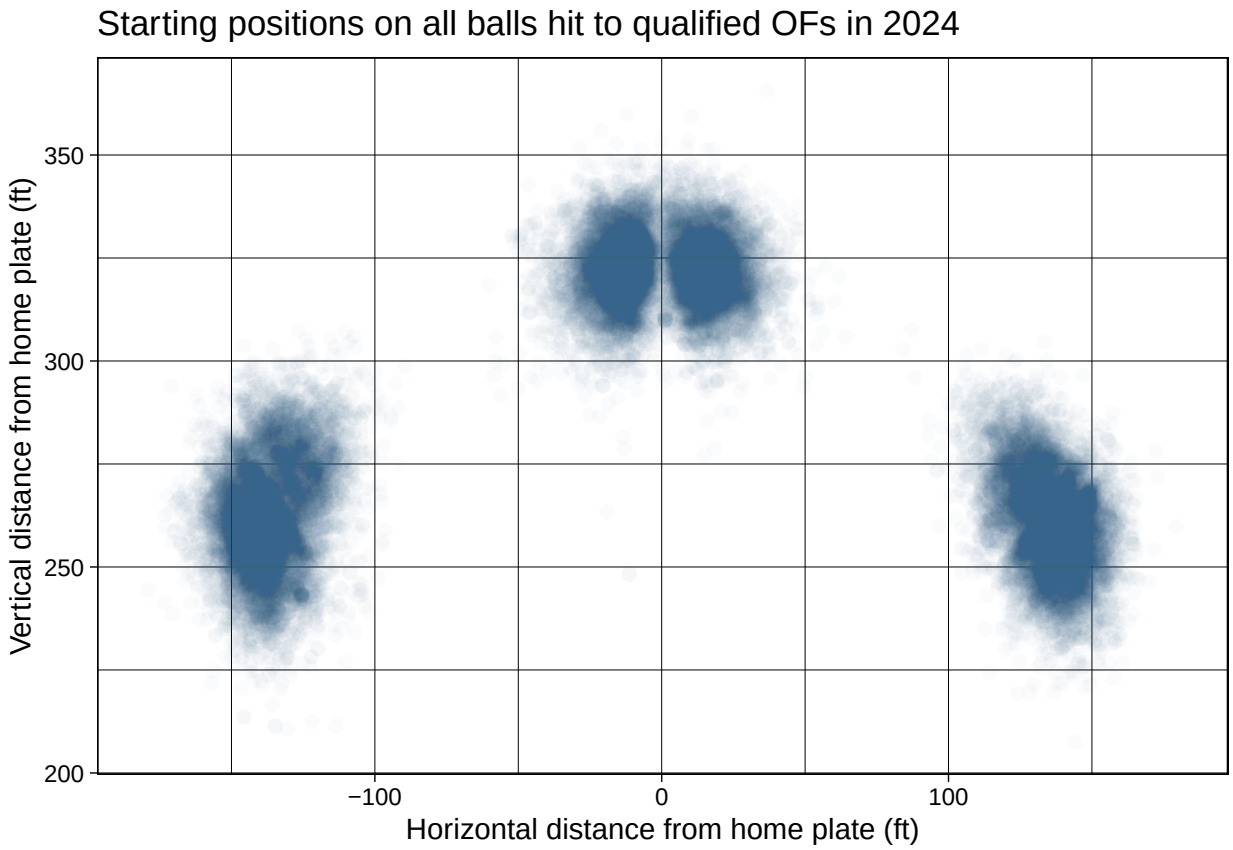
January 2nd

```
jan2_1 <- of_catch_prob_2024 %>%
            ggplot(aes(x = start_pos_x, y = start_pos_y)) +
            geom_point(col = "steelblue4", size = 2, shape = 19) +
            labs(title = "Starting positions on all balls hit to qualified OFs in 2024",
                 x = "Horizontal distance from home plate (ft)",
                 y = "Vertical distance from home plate (ft)") +
            theme_linedraw()

jan2_1
```



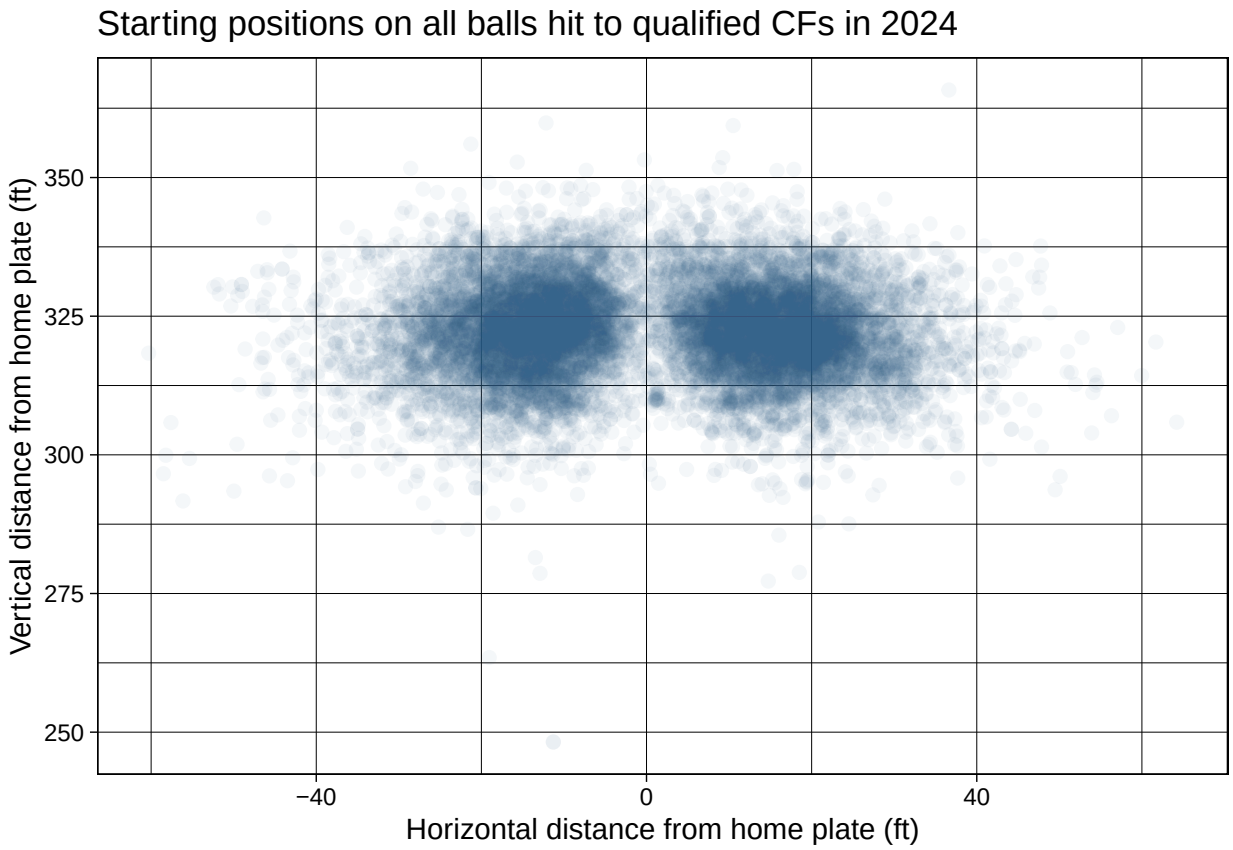

```
ggsave("../figures/jan2_1.png", plot = jan2_1)
```

```
jan2_2 <- of_catch_prob_2024 %>%
            ggplot(aes(x = start_pos_x, y = start_pos_y)) +
            geom_point(col = "steelblue4", size = 2, shape = 19, alpha = 0.025) +
            labs(title = "Starting positions on all balls hit to qualified OFs in 2024",
                 x = "Horizontal distance from home plate (ft)",
                 y = "Vertical distance from home plate (ft)") +
            theme_linedraw()

jan2_2
```




```
ggsave("../figures/jan2_2.png", plot = jan2_2)
```

```
jan2_3 <- of_catch_prob_2024 %>%
            filter(pos == 8) %>%
            ggplot(aes(x = start_pos_x, y = start_pos_y)) +
            geom_point(col = "steelblue4", size = 2, shape = 19, alpha = 0.05) +
            labs(title = "Starting positions on all balls hit to qualified CFs in 2024",
                 x = "Horizontal distance from home plate (ft)",
                 y = "Vertical distance from home plate (ft)") +
            theme_linedraw()

jan2_3
```




```
ggsave("../figures/jan2_3.png", plot = jan2_3)
```

January 4th

```
single_game_oaa <- of_catch_prob_2024 %>%
                    group_by(game_pk, player) %>%
                    summarize(oaa = sum(out * (1 - catch_rate) - (1 - out) * catch_rate),
                              opportunities = n(),
                              catches = sum(out),
                              stars5_opps = sum(stars == 5),
                              stars5_catches = sum(stars == 5 & out == 1),
                              stars4_opps = sum(stars == 4),
                              stars4_catches = sum(stars == 4 & out == 1),
                              stars3_opps = sum(stars == 3),
                              stars3_catches = sum(stars == 3 & out == 1),
                              stars2_opps = sum(stars == 2),
                              stars2_catches = sum(stars == 2 & out == 1),
                              stars1_opps = sum(stars == 1),
                              stars1_catches = sum(stars == 1 & out == 1),
                              stars0_opps = sum(stars == 0),
                              stars0_catches = sum(stars == 0 & out == 1),
                              .groups = "drop")
```

```
single_game_oaa %>%
  arrange(desc(oaa)) %>%
  head(10)
```

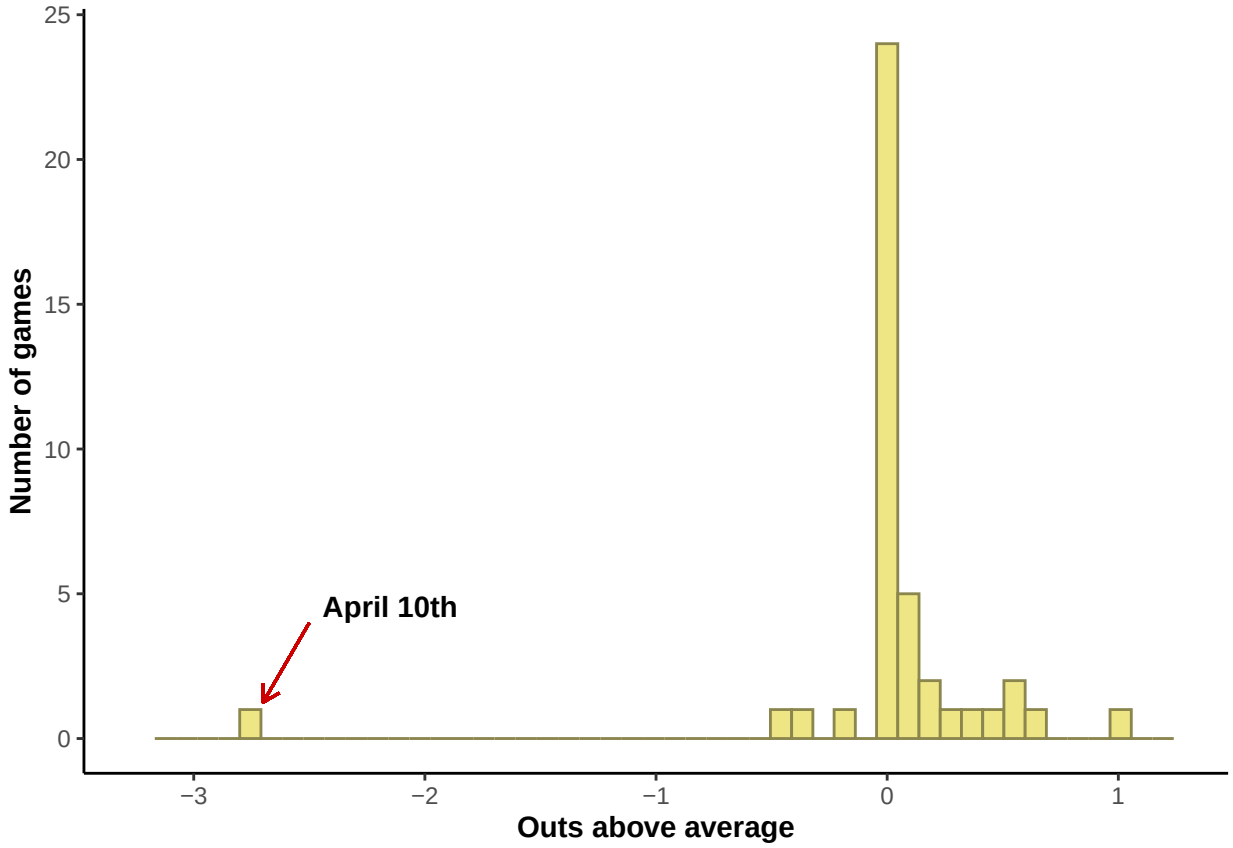
```
## # A tibble: 10 x 17
##    game_pk player           oaa opportunities catches stars5_opps stars5_catches
##      <dbl> <chr>          <dbl>         <int>   <dbl>       <int>          <int>
##  1  745455 Jacob Young     1.84             8       8           2              2
##  2  746097 Pete Crow-Arm~  1.68             6       6           2              2
##  3  747064 Tyrone Taylor   1.64             6       6           2              2
##  4  745277 Julio Rodrígu~  1.61             4       4           1              1
##  5  747121 Fernando Tati~  1.52             4       4           2              2
##  6  745184 Victor Scott ~  1.42             4       4           0              0
##  7  744844 Jacob Young     1.39             6       6           1              1
##  8  745716 Tyrone Taylor   1.31             3       3           1              1
##  9  745075 Pete Crow-Arm~  1.3              2       2           1              1
## 10  745713 Mickey Moniak   1.28            16      14           2              0
## # i 10 more variables: stars4_opps <int>, stars4_catches <int>,
## #   stars3_opps <int>, stars3_catches <int>, stars2_opps <int>,
## #   stars2_catches <int>, stars1_opps <int>, stars1_catches <int>,
## #   stars0_opps <int>, stars0_catches <int>
```

January 6th

```
single_game_oaa %>%
  arrange(oaa) %>%
  head(10)
```

```
## # A tibble: 10 x 17
##    game_pk player           oaa opportunities catches stars5_opps stars5_catches
##      <dbl> <chr>          <dbl>         <int>   <dbl>       <int>          <int>
##  1  745196 Victor Scott ~ -2.71             6       3           0              0
##  2  746262 MJ Melendez    -2.57             6       2           0              0
##  3  746546 Charlie Black~ -2.34             5       1           1              0
##  4  746931 Tyler O'Neill  -2.33             5       2           0              0
##  5  745708 Juan Soto      -2.18             6       2           0              0
##  6  746677 Will Benson    -2.11             6       3           1              0
##  7  745342 Luis Matos     -2.07             7       2           3              0
##  8  746481 Alec Burleson  -2.04            10       6           2              0
##  9  746971 Ian Happ       -2.04             4       1           0              0
## 10  745184 Alec Burleson  -1.98             2       0           0              0
## # i 10 more variables: stars4_opps <int>, stars4_catches <int>,
## #   stars3_opps <int>, stars3_catches <int>, stars2_opps <int>,
## #   stars2_catches <int>, stars1_opps <int>, stars1_catches <int>,
## #   stars0_opps <int>, stars0_catches <int>
```

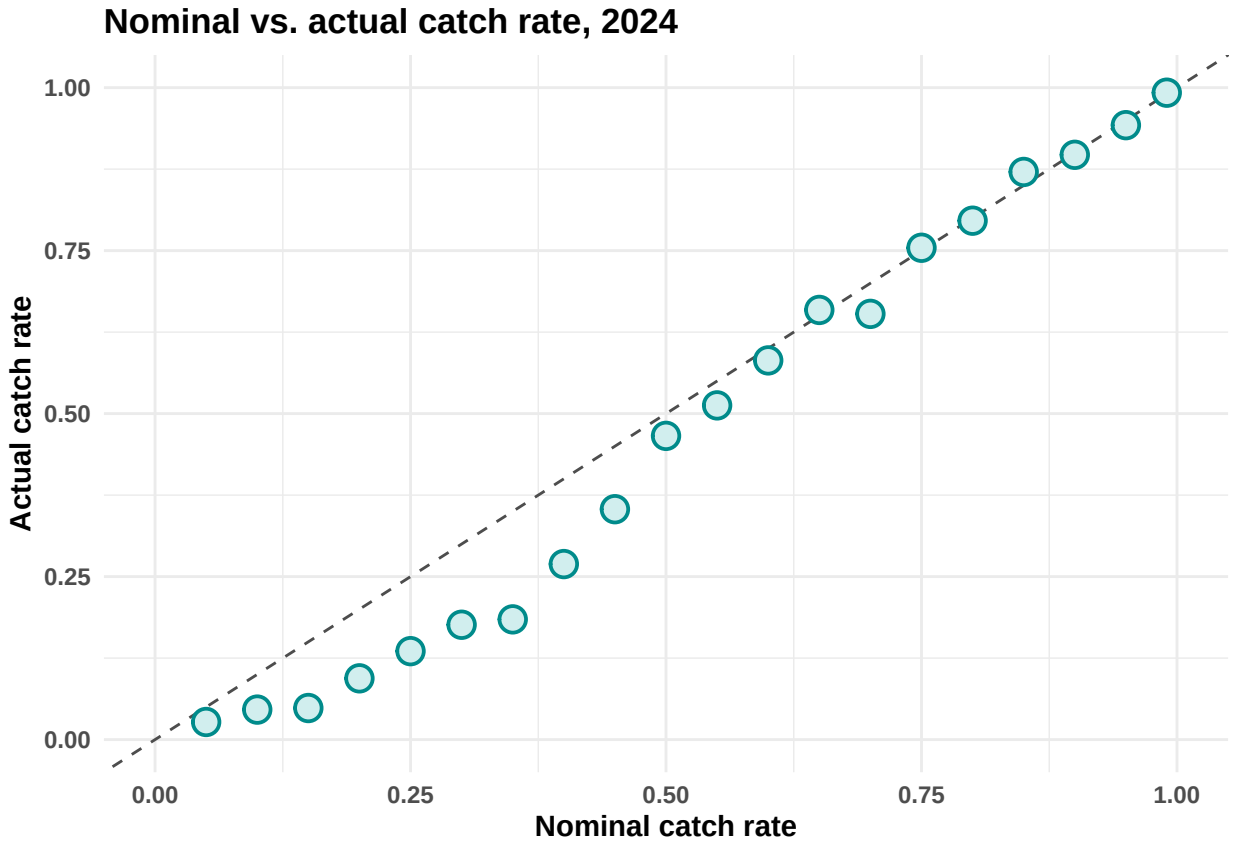
```
jan6 <- single_game_oaa %>%
          filter(player == "Victor Scott II") %>%
          ggplot() +
            geom_histogram(aes(x = oaa), bins = 50, fill = "khaki2", col = "khaki4") +
            geom_segment(x = -2.5, y = 4, xend = -2.7, yend = 1.25,
                         arrow = arrow(length = unit(0.25, "cm")),
                         col = "red3") +
            geom_text(x = -2.15, y = 4.55, label = "April 10th", check_overlap = TRUE, fontface = "bold
            labs(x = "Outs above average", y = "Number of games") +
            xlim(c(-3.25, 1.25)) +
            theme_classic() + theme(axis.title = element_text(face = "bold"))

jan6
```




```
ggsave("../figures/jan6.png", plot = jan6, height = 4, width = 6)
```

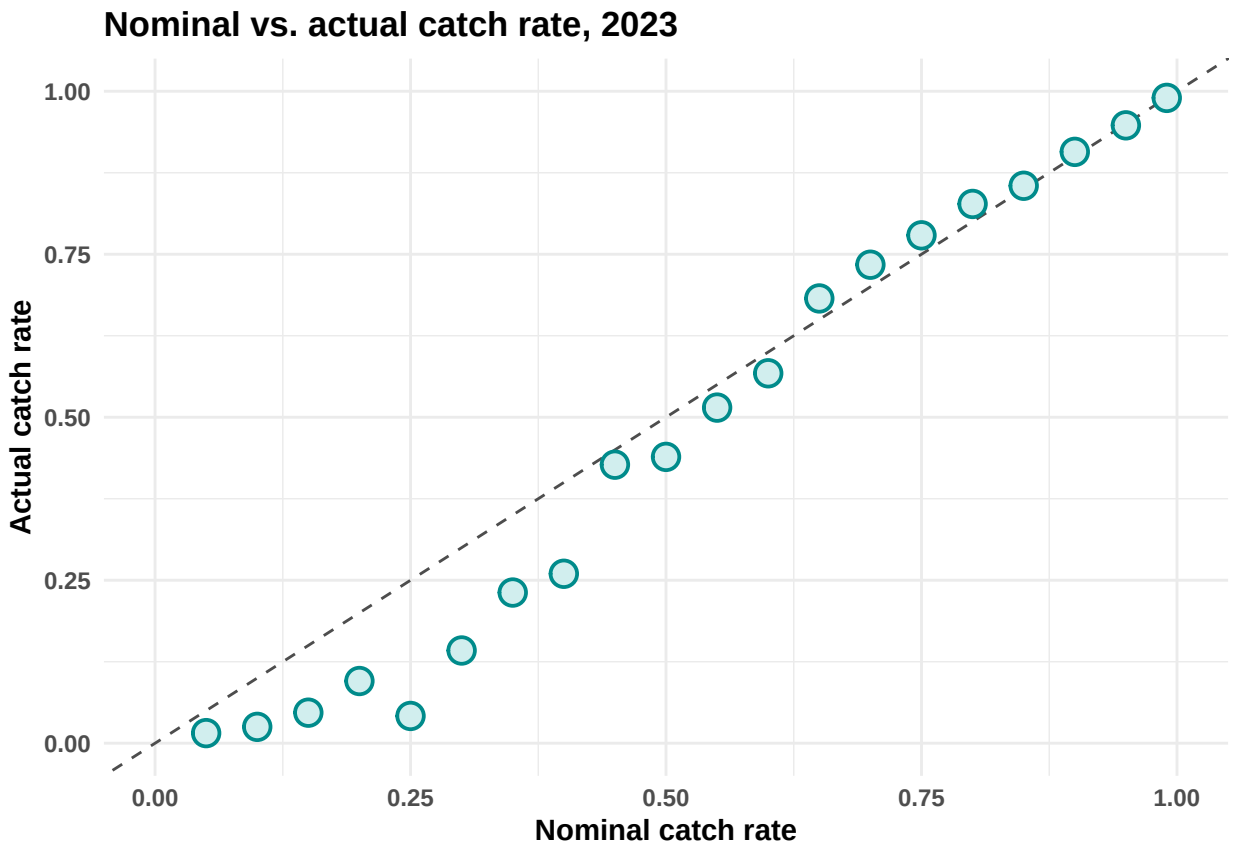
January 7th

```
calibration_table_2024 <- of_catch_prob_2024 %>%
                          group_by(catch_rate) %>%
                          summarize(actual_catch_rate = mean(out)) %>%
                          rename(nominal_catch_rate = catch_rate)

jan7_1 <- calibration_table_2024 %>%
            ggplot(aes(x = nominal_catch_rate, y = actual_catch_rate)) +
              geom_abline(intercept = 0, slope = 1,
                          color = "gray30", linetype = "dashed", linewidth = 0.5) +
              geom_point(pch = 21, col = "cyan4", fill = "lightcyan2",
                         size = 4, stroke = 1) +
              theme_minimal() +
              lims(x = c(0,1), y = c(0,1)) +
              labs(x = "Nominal catch rate", y = "Actual catch rate",
                   title = "Nominal vs. actual catch rate, 2024") +
              theme(axis.title = element_text(face = "bold"),
                    axis.text = element_text(face = "bold"),
                    title = element_text(face = "bold"))

jan7_1
```




```
ggsave("../figures/jan7_1.png", plot = jan7_1, height = 4, width = 6)
```

```
calibration_table_2023 <- of_catch_prob_2023 %>%
                          group_by(catch_rate) %>%
                          summarize(actual_catch_rate = mean(out)) %>%
                          rename(nominal_catch_rate = catch_rate)

jan7_2 <- calibration_table_2023 %>%
            ggplot(aes(x = nominal_catch_rate, y = actual_catch_rate)) +
              geom_abline(intercept = 0, slope = 1,
                          color = "gray30", linetype = "dashed", linewidth = 0.5) +
              geom_point(pch = 21, col = "cyan4", fill = "lightcyan2",
                         size = 4, stroke = 1) +
              theme_minimal() +
              lims(x = c(0,1), y = c(0,1)) +
              labs(x = "Nominal catch rate", y = "Actual catch rate",
                   title = "Nominal vs. actual catch rate, 2023") +
              theme(axis.title = element_text(face = "bold"),
                    axis.text = element_text(face = "bold"),
                    title = element_text(face = "bold"))

jan7_2
```



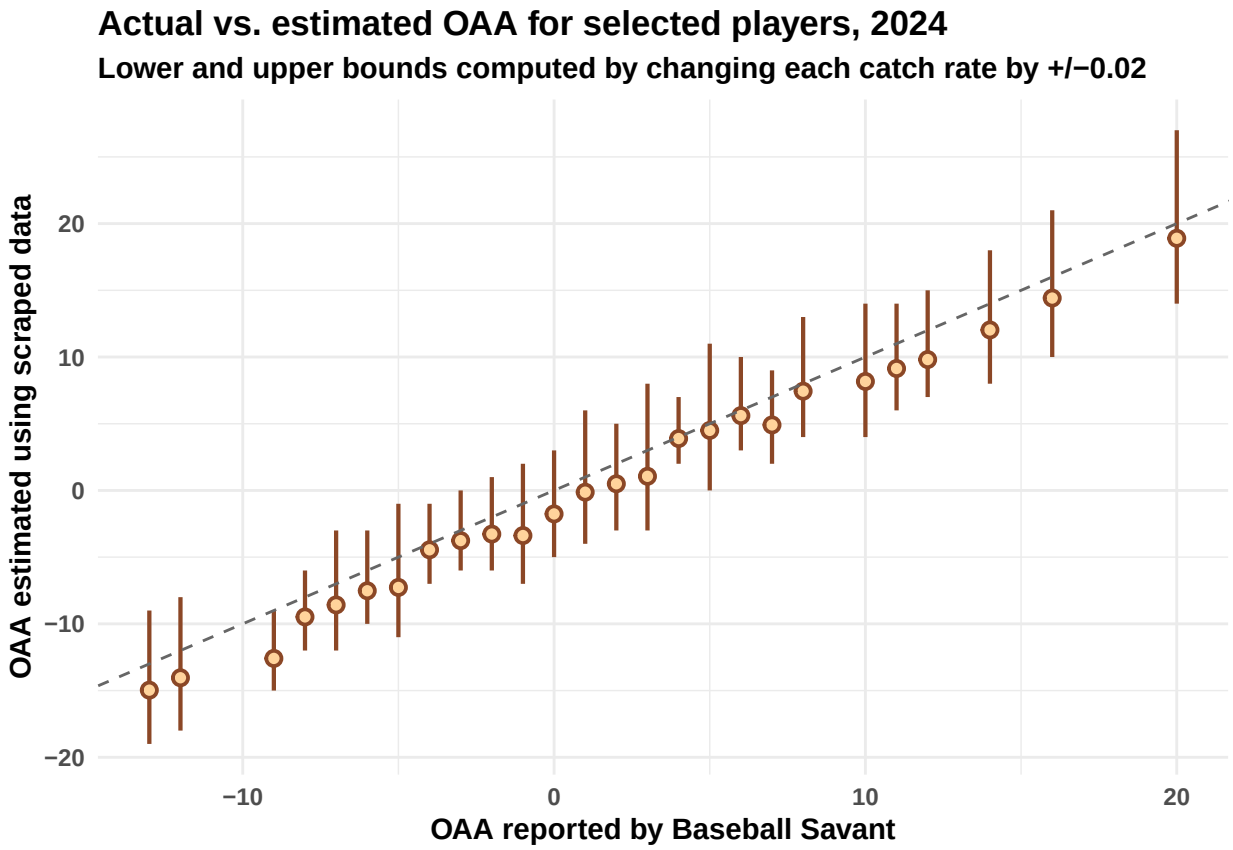

```
ggsave("../figures/jan7_2.png", plot = jan7_2, height = 4, width = 6)
```

January 8th

```
of_oaa_2024 <- read_csv("../data/of_oaa_2024.csv")

oaa_rounding_check <- of_catch_prob_2024 %>%
                        mutate(catch_rate_upper = pmin(0.999999, catch_rate - 0.02),
                               catch_rate_lower = pmin(0.999999, catch_rate + 0.02)) %>%
                        group_by(player_id, player) %>%
                        summarize(opp = n(),
                                  oaa_lower = round(sum(out * (1 - catch_rate_lower) - (1 - out) * catch
                                  oaa_estimate = sum(out * (1 - catch_rate) - (1 - out) * catch_rate),
                                  oaa_upper = round(sum(out * (1 - catch_rate_upper) - (1 - out) * catch
                        ungroup() %>%
                        left_join(of_oaa_2024, by = "player_id") %>%
                        select(player_id, name = player, opp,
                               oaa_lower, oaa_estimate, oaa_upper, oaa_true = oaa)

oaa_rounding_check %>%
  summarize(any(oaa_true < oaa_lower | oaa_true > oaa_upper))
```

```
## # A tibble: 1 x 1
##   `any(oaa_true < oaa_lower | oaa_true > oaa_upper)`
##   <lgl>
## 1 FALSE
```

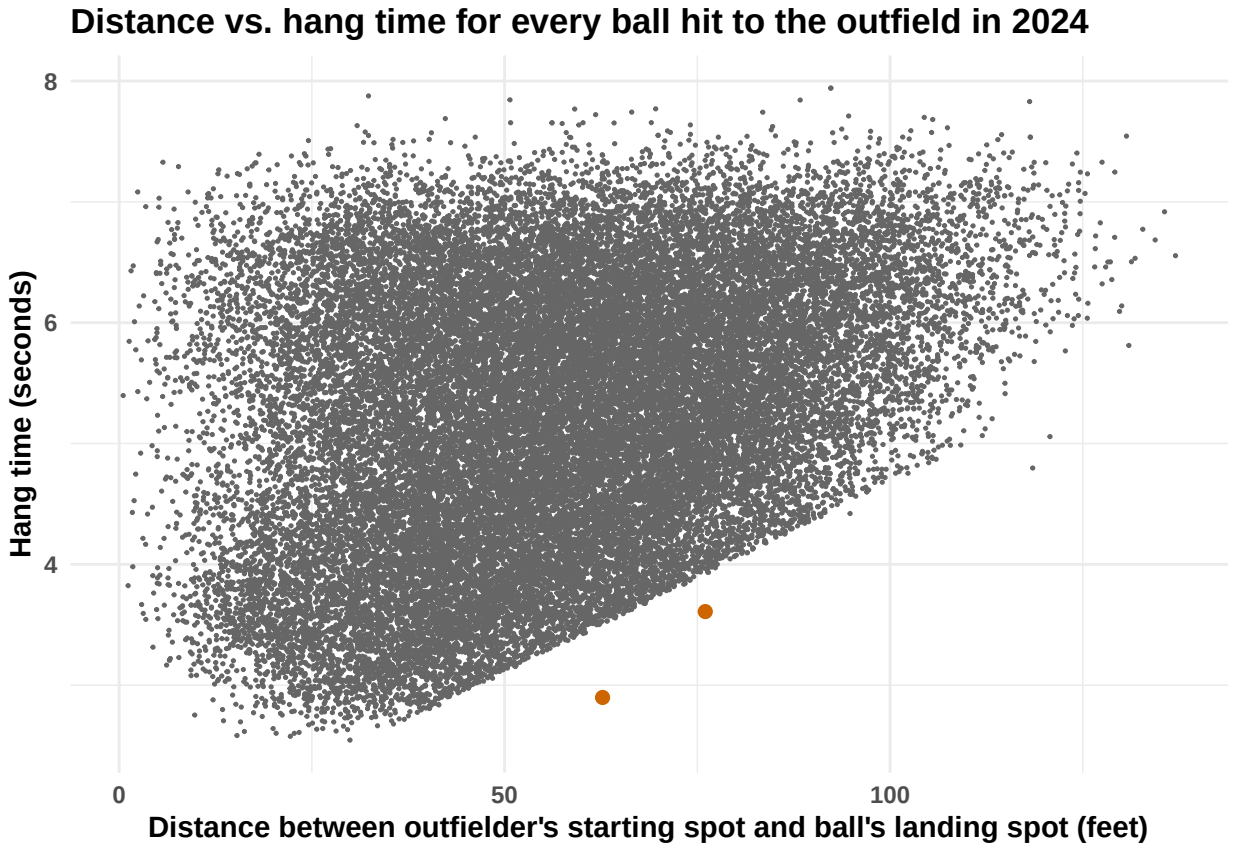
```
set.seed(0)
jan8 <- oaa_rounding_check %>%
          filter(opp > 162) %>%
          group_by(oaa_true) %>%
          sample_n(1) %>%
          ggplot(aes(x = oaa_true, y = oaa_estimate)) +
            geom_linerange(aes(ymin = oaa_lower, ymax = oaa_upper), col = "sienna4", linewidth = 0.75) +
            geom_point(size = 2, stroke = 1, pch = 21, fill = "burlywood1", col = "sienna4") +
            geom_abline(intercept = 0, slope = 1, linetype = "dashed", col = "gray40") +
            theme_minimal() +
            labs(x = "OAA reported by Baseball Savant",
                 y = "OAA estimated using scraped data",
                 title = "Actual vs. estimated OAA for selected players, 2024",
                 subtitle = "Lower and upper bounds computed by changing each catch rate by +/-0.02") +
            theme(axis.title = element_text(face = "bold"),
                  axis.text = element_text(face = "bold"),
                  title = element_text(face = "bold"))

jan8
```




```
ggsave("../figures/jan8.png", plot = jan8, height = 4, width = 6)
```

January 9th

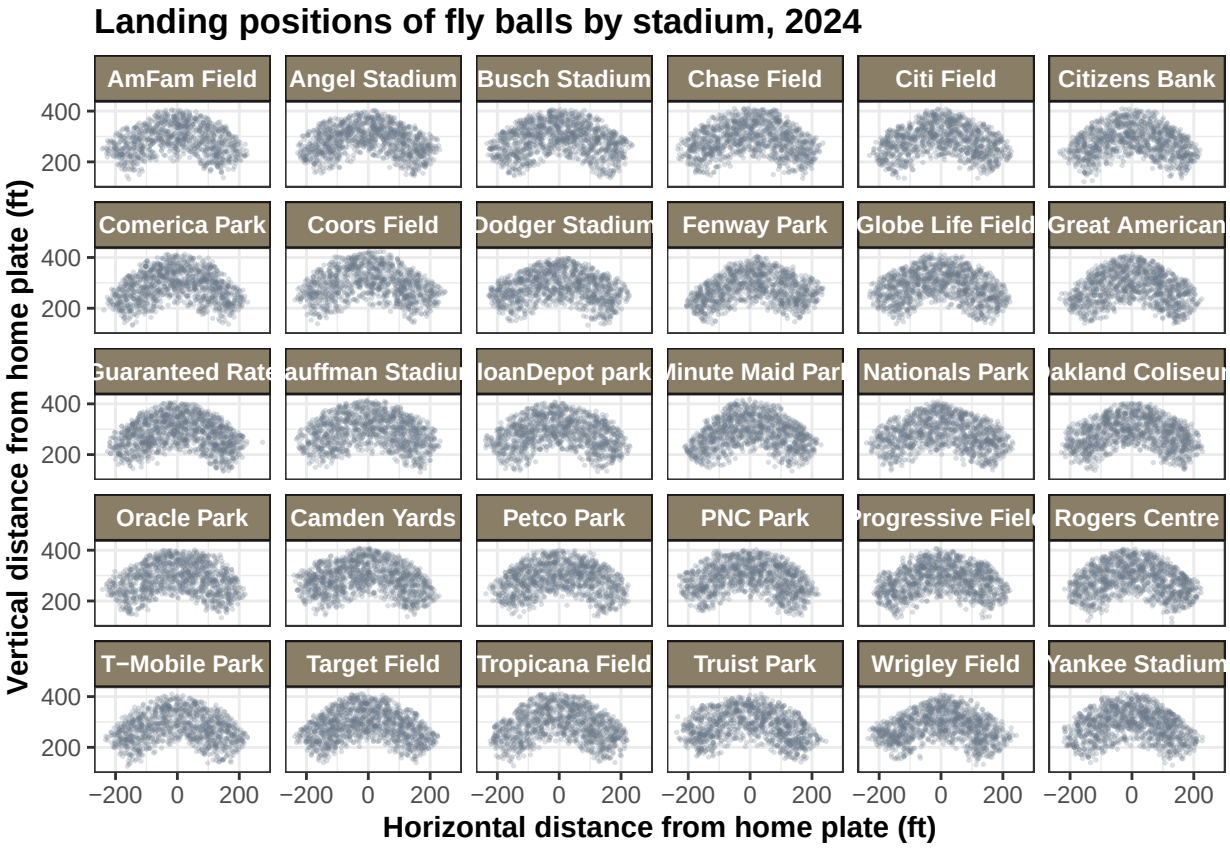
```
jan9 <- of_catch_prob_2024 %>%
          mutate(highlight = (hang_time < 3 & distance > 50) | (hang_time < 3.8 & distance > 75)) %>%
          ggplot(aes(x = distance, y = hang_time, col = highlight, size = highlight)) +
            geom_point() +
            scale_colour_manual(values = c("gray40", "darkorange3")) +
            scale_size_manual(values = c(0.25, 2)) +
            theme_minimal() +
            theme(legend.position = "none",
                  axis.title = element_text(face = "bold"),
                  axis.text = element_text(face = "bold"),
                  title = element_text(face = "bold")) +
            labs(x = "Distance between outfielder's starting spot and ball's landing spot (feet)",
                 y = "Hang time (seconds)",
                 title = "Distance vs. hang time for every ball hit to the outfield in 2024")

jan9
```




```
ggsave("../figures/jan9.png", plot = jan9, height = 4, width = 6)
```

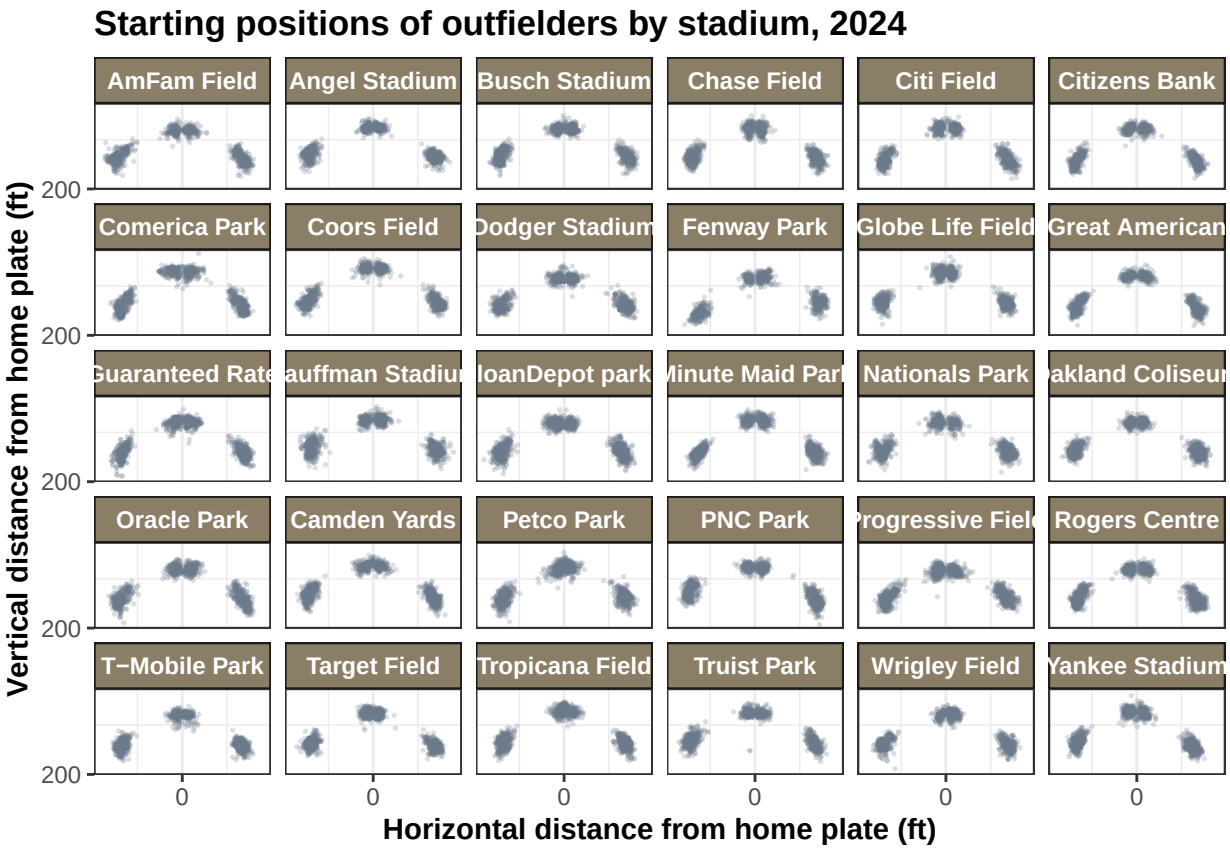
January 17th

```
jan17_1 <- of_catch_prob_2024 %>%
              mutate(stadium = fct_recode(stadium,
                                          "AmFam Field" = "American Family Field",
                                          "Guaranteed Rate" = "Guaranteed Rate Field",
                                          "Camden Yards" = "Oriole Park at Camden Yards",
                                          "Great American" = "Great American Ball Park",
                                          "Citizens Bank" = "Citizens Bank Park"
              )) %>%
              ggplot(aes(x = landing_pos_x, y = landing_pos_y)) +
                geom_point(size = 0.25, alpha = 0.25, col = "slategray4") +
                facet_wrap(~stadium, scales = "fixed") +
                theme_bw() +
                labs(x = "Horizontal distance from home plate (ft)",
                     y = "Vertical distance from home plate (ft)",
                     title = "Landing positions of fly balls by stadium, 2024") +
                theme(axis.title = element_text(face = "bold"),
                      title = element_text(face = "bold"),
                      plot.subtitle = element_text(face = "italic"),
                      strip.background = element_rect(fill = "wheat4", color = "gray10"),
                      strip.text = element_text(face = "bold", color = "white")) +
                scale_x_continuous(breaks = c(-200, 0, 200)) +
                scale_y_continuous(breaks = c(200, 400))

jan17_1
```




```
ggsave("../figures/jan17_1.png", plot = jan17_1, height = 6, width = 8)
```

```
jan17_2 <- of_catch_prob_2024 %>%
              mutate(stadium = fct_recode(stadium,
                                          "AmFam Field" = "American Family Field",
                                          "Guaranteed Rate" = "Guaranteed Rate Field",
                                          "Camden Yards" = "Oriole Park at Camden Yards",
                                          "Great American" = "Great American Ball Park",
                                          "Citizens Bank" = "Citizens Bank Park"
              )) %>%
              ggplot(aes(x = start_pos_x, y = start_pos_y)) +
                geom_point(size = 0.25, alpha = 0.25, col = "slategray4") +
                facet_wrap(~stadium, scales = "fixed") +
                theme_bw() +
                labs(x = "Horizontal distance from home plate (ft)",
                     y = "Vertical distance from home plate (ft)",
                     title = "Starting positions of outfielders by stadium, 2024") +
                theme(axis.title = element_text(face = "bold"),
                      title = element_text(face = "bold"),
                      plot.subtitle = element_text(face = "italic"),
                      strip.background = element_rect(fill = "wheat4", color = "gray10"),
                      strip.text = element_text(face = "bold", color = "white")) +
                scale_x_continuous(breaks = c(-200, 0, 200)) +
                scale_y_continuous(breaks = c(200, 400))

jan17_2
```




```
ggsave("../figures/jan17_2.png", plot = jan17_2, height = 6, width = 8)
```

January 18th

```
stadium_dims <- of_catch_prob_2024 %>%
                  distinct(stadium, .keep_all = TRUE) %>%
                  select(stadium, starts_with("wall_height"), starts_with("dist_"))

pca <- prcomp(stadium_dims %>% select(-stadium), center = TRUE, scale = TRUE)

pca
```

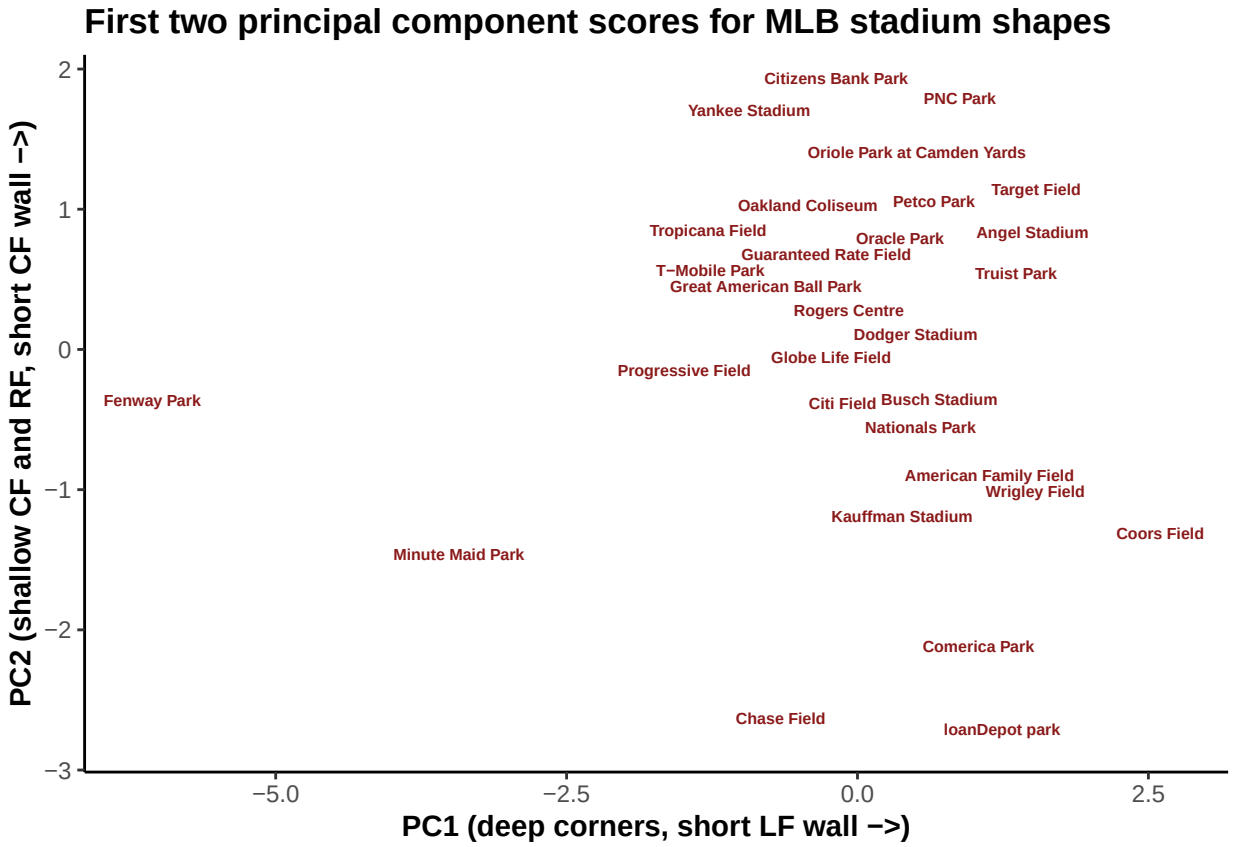
```
## Standard deviations (1, .., p=8):
## [1] 1.6133522 1.2413816 1.0530766 1.0052921 0.9336312 0.7679162 0.4447214
## [8] 0.2781085
##
## Rotation (n x k) = (8 x 8):
##                          PC1         PC2         PC3        PC4         PC5
## wall_height_lf -0.52563253 -0.16252938  0.01261898 -0.2306161  0.31539308
## wall_height_cf -0.21369818 -0.46724246  0.45415128 -0.2028672 -0.24556732
## wall_height_rf  0.28717525  0.28246940  0.35896996  0.1042763  0.67175299
## dist_lf         0.48507818 -0.28088096  0.01297260 -0.3375695  0.32213101
## dist_lc         0.46879974  0.06248463  0.25797717  0.2568213 -0.47910240
## dist_cf        -0.01629932 -0.35294451 -0.50995086  0.6384369  0.17928122
## dist_rc         0.04235743 -0.56952669  0.41248946  0.3622816  0.14825164
## dist_rf         0.37207533 -0.37914483 -0.40964618 -0.4195565 -0.03929392
##                          PC6         PC7         PC8
## wall_height_lf  0.00962424  0.69004304 -0.26120262
## wall_height_cf  0.59259431 -0.26984609 -0.06573315
## wall_height_rf  0.43090688  0.08794958  0.23095562
## dist_lf        -0.19532159 -0.19154215 -0.62695794
## dist_lc         0.14069505  0.57057383 -0.26253451
## dist_cf         0.35684595 -0.04124903 -0.21524573
## dist_rc        -0.49849021  0.06888202  0.31182355
## dist_rf         0.17111831  0.27312902  0.51821479
```

```
summary(pca)
```

```
## Importance of components:
##                           PC1    PC2    PC3    PC4    PC5     PC6     PC7
## Standard deviation     1.6134 1.2414 1.0531 1.0053 0.9336 0.76792 0.44472
## Proportion of Variance 0.3254 0.1926 0.1386 0.1263 0.1090 0.07371 0.02472
## Cumulative Proportion  0.3254 0.5180 0.6566 0.7829 0.8919 0.96561 0.99033
##                           PC8
## Standard deviation     0.27811
## Proportion of Variance 0.00967
## Cumulative Proportion  1.00000
```

```
set.seed(18)

jan18 <- tibble(stadium = stadium_dims$stadium,
                pc1 = pca$x[,1], pc2 = pca$x[,2], pc3 = pca$x[,3]) %>%
            ggplot(aes(x = pc1, y = pc2)) +
```

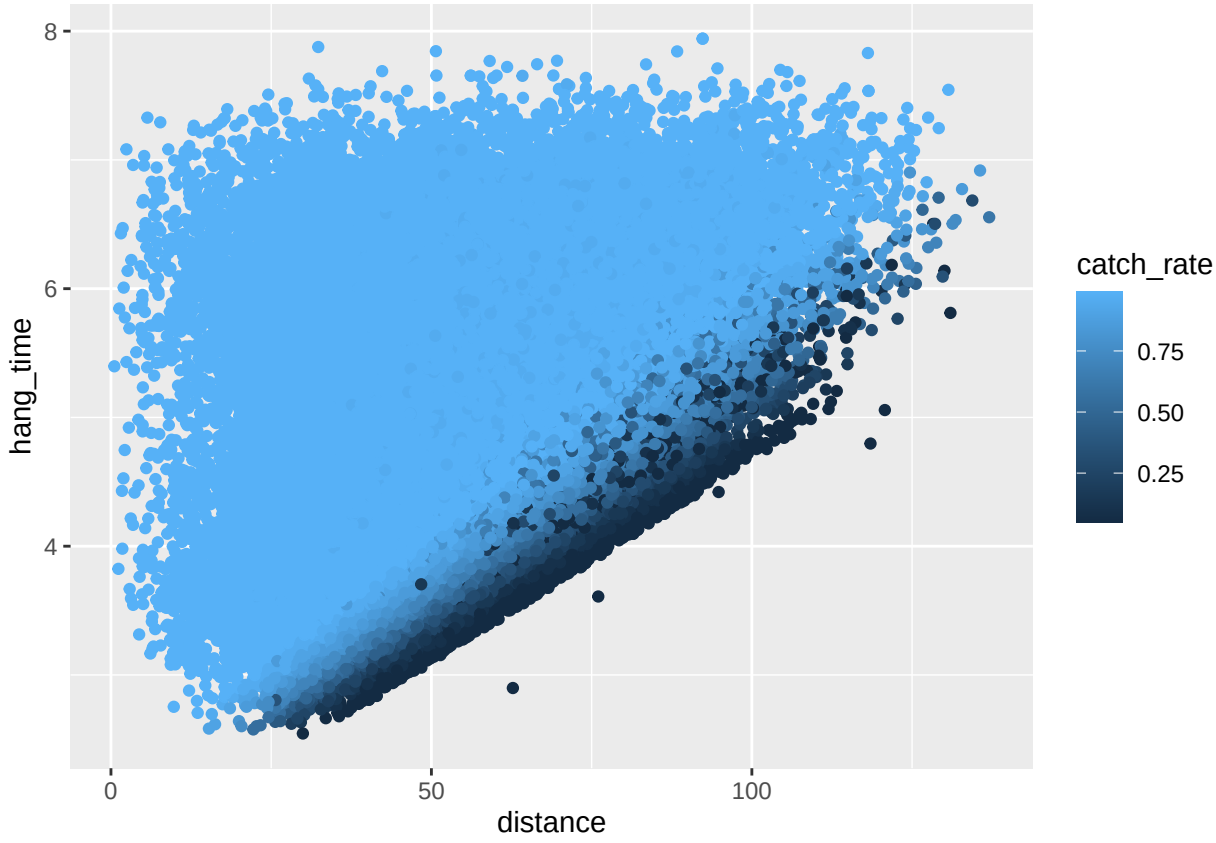
```
              ggrepel::geom_text_repel(aes(label = stadium), fontface = "bold", col = "firebrick4",
                                       min.segment.length = 1,
                                       label.padding = 0.0, box.padding = 0.05, point.padding = 0,
                                       size = 2, max.overlaps = 30) +
              theme_classic() +
              labs(title = "First two principal component scores for MLB stadium shapes",
                   x = "PC1 (deep corners, short LF wall ->)",
                   y = "PC2 (shallow CF and RF, short CF wall ->)") +
              theme(axis.title = element_text(face = "bold"),
                    title = element_text(face = "bold"))

jan18
```



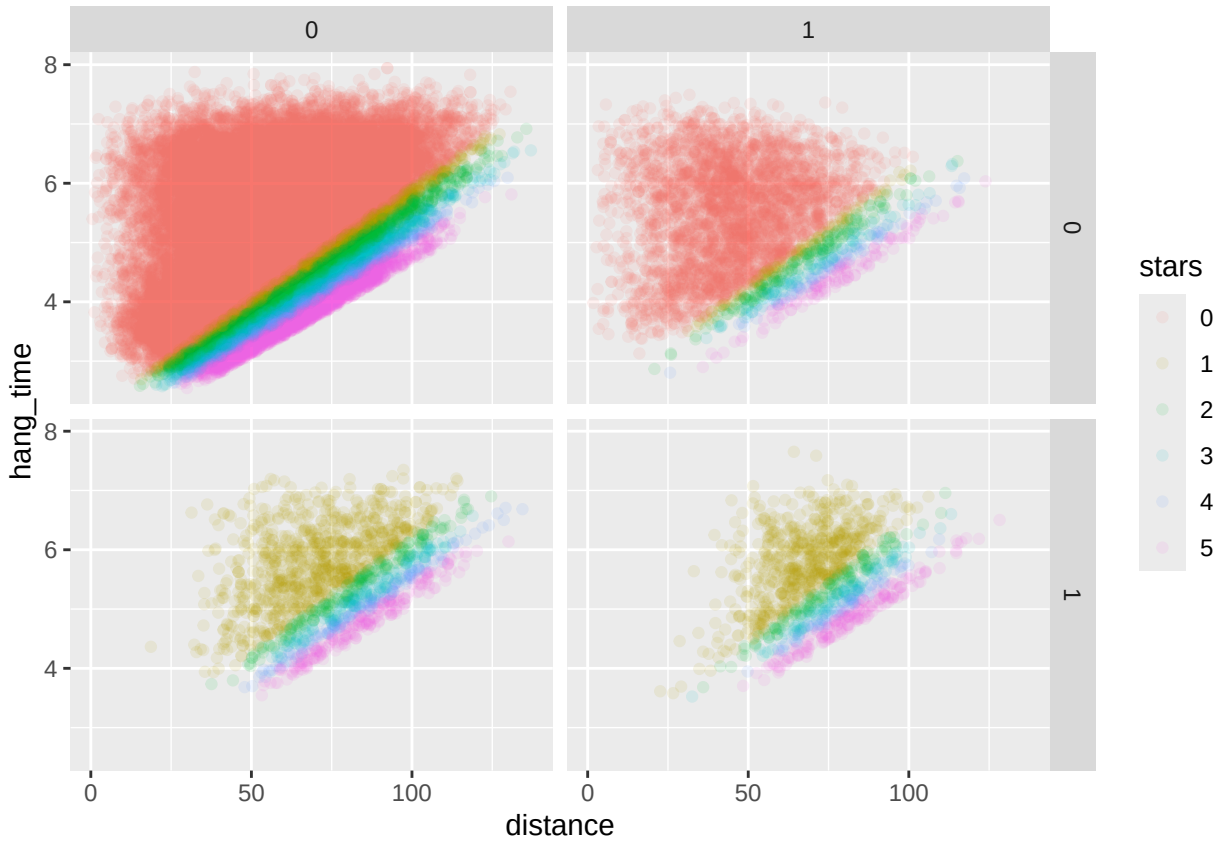

```
ggsave("../figures/jan18.png", plot = jan18, height = 4, width = 6)
```

Later

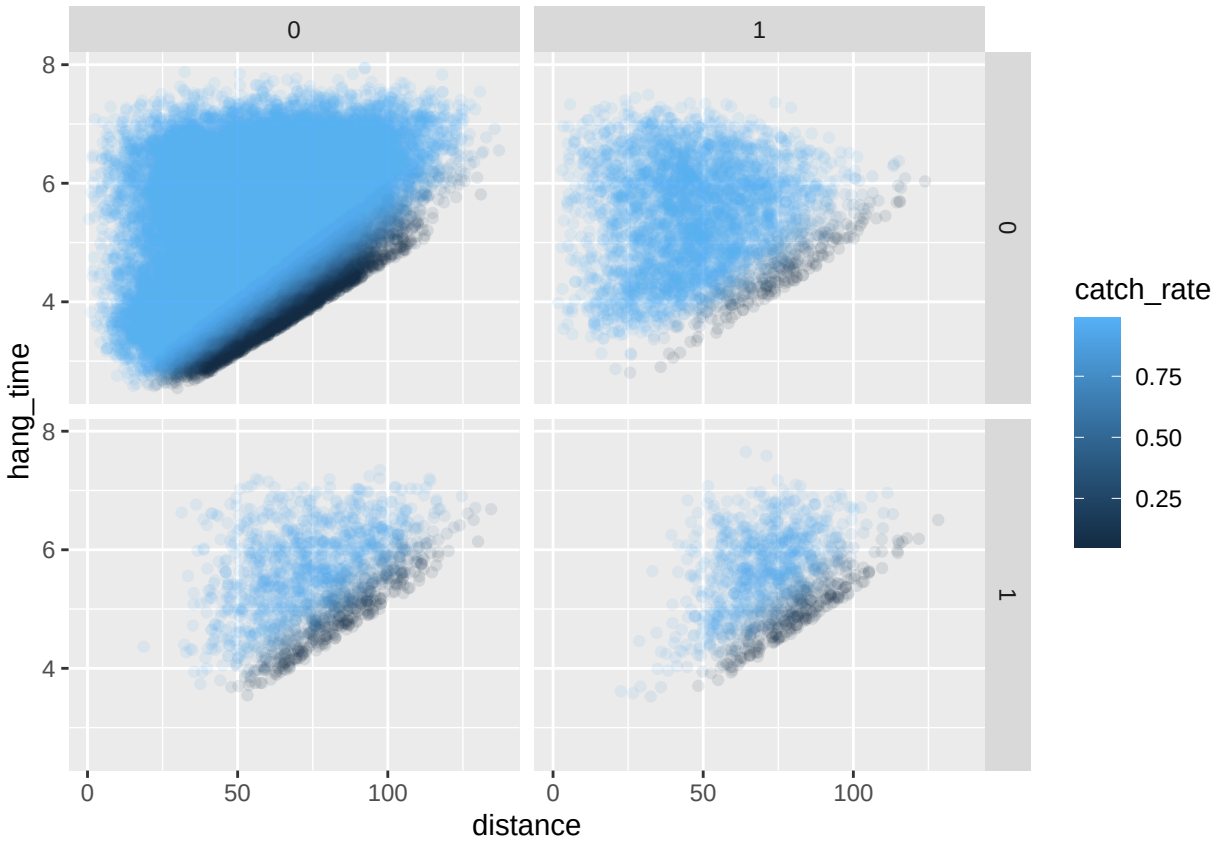
```
of_catch_prob_2024 %>%
  ggplot(aes(x = distance, y = hang_time, col = catch_rate)) +
    geom_point(alpha = 1)
```




```
of_catch_prob_2024 %>%
  filter(stars <= 5) %>%
  mutate(stars = as.factor(stars)) %>%
  ggplot(aes(x = distance, y = hang_time, col = stars)) +
    geom_point(alpha = 0.1) +
    facet_grid(rows = vars(wall), cols = vars(back))
```




```
of_catch_prob_2024 %>%
  filter(stars <= 5) %>%
  mutate(stars = as.factor(stars)) %>%
  ggplot(aes(x = distance, y = hang_time, col = catch_rate)) +
    geom_point(alpha = 0.1) +
    facet_grid(rows = vars(wall), cols = vars(back))
```


0
1
0
1
8
6
4
hang_time
0
50
100
distance
catch_rate
0.75
0.50
0.25