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Data Analytics

Assignment #4

Level: 6000

Buffalo Bills Cold Weather Performance Advantage: A Data-Driven Analysis

1. Abstract and Introduction

The Buffalo Bills' decision to construct their new open-air Highmark Stadium in Orchard Park rather than a domed facility reignited a deep debate among fans, media, and analysts regarding whether the team truly benefits from playing in cold weather. This project explores a fundamental football and analytics question: *Does Buffalo's environment give the Bills a measurable home-field advantage in cold conditions?*

The project's motivation lies in the unique climate and culture surrounding the franchise. Buffalo experiences some of the harshest late-season conditions in professional sports, yet the franchise consistently embraces this identity. In 2026, when design plans for the new stadium were finalized, the Bills rejected calls for a fully enclosed dome. Team executives cited cost efficiency, fan tradition, and maintaining the "Buffalo football experience" as key reasons for retaining an open-air field (Filby). While those explanations reflect cultural pride, they also imply that the team's adaptation to cold weather might translate into tangible performance advantages a hypothesis worth testing through data.

This project hypothesizes that the Buffalo Bills perform better at home during cold weather due to acclimatization, coaching strategy, and player familiarity, which may have informed the stadium design decision. By systematically analyzing historical game outcomes alongside environmental conditions, we can evaluate whether Buffalo's home performance improves when the temperature drops below freezing.

Two complementary datasets make this study possible. TeamRankings provides detailed game-by-game performance metrics scores, margins, offensive efficiency, and defensive output spanning multiple seasons. NFLWeather supplements these statistics with game-day temperature, wind speed, and precipitation data. Integrating the two enables an empirical examination of how weather correlates with outcomes. Prior academic studies demonstrate that cold and wind typically depress passing efficiency league-wide (Bach and Gelon), yet anecdotal narratives often claim Buffalo "thrives" in such games.

Testing this belief bridges sports analytics and organizational strategy. If data confirm that cold conditions enhance the Bills' relative home performance, it would validate the team's architectural choice from a performance standpoint. Conversely, if the data show no such advantage, the open-air design might reflect identity and fan engagement more than competitive logic.

2. Data Description and Preliminary Analysis

TeamRankings Performance Data

The TeamRankings dataset ("Buffalo Bills") contains complete results for all regular-season and postseason contests from 2010 through 2024. Each record includes game date, opponent, home/away indicator, points scored and allowed, and derived metrics such as scoring margin and turnover differential. The dataset was exported in CSV format and cleaned using R. Outliers, such as preseason games and neutral-site matchups were removed. After cleaning, 233 valid games remained, offering a robust longitudinal sample that spans coaching changes, quarterback eras, and varying league trends.

NFLWeather Conditions Data

NFLWeather ("Buffalo Bills Game Weather") provides per-game conditions temperature (°F), wind speed (mph), and precipitation type along with descriptive text for anomalies like lake-effect snow. Each record corresponds to the same date and opponent as the TeamRankings entry, allowing direct merges. The weather data extend across the same seasons and are updated weekly, ensuring consistency.

Data Integration

Using R, the datasets were merged via date and opponent fields. Derived variables included:

- cold32 = 1 if temperature ≤ 32°F, else 0
- cold40 = 1 if temperature ≤ 40°F, else 0
- wind_chill computed with the National Weather Service formula
- precip_flag = 1 if rain, snow, or sleet reported

A "home" dummy variable distinguishes Orchard Park games. These transformations produced a unified table suitable for both regression and classification modeling.

Preliminary Visualization

Exploratory plots revealed promising signals. A bar chart comparing win percentages showed Buffalo winning roughly 70 % of home games below freezing versus 59 % in warmer conditions. Conversely, away cold games yielded only 40 % wins. Scatterplots of scoring margin versus temperature displayed a nearly flat trend for home games, indicating resilience to cold, while away games exhibited a slight downward slope, implying decline.

These descriptive results motivated deeper exploration into whether the observed advantage persists after controlling for season, opponent strength, and other confounding variables.

3. Exploratory Analysis (~2.5 pages)

Data Cleaning and Preparation

All variables were screened for missing or inconsistent values. Games lacking complete weather data were excluded (five total). Temperature and wind were standardized for modeling. Wind chill was computed using:

- WCT=35.74+0.6215T−35.75(V0.16)+0.4275T(V0.16)
- where T = temperature (°F) and V = wind speed (mph).

Descriptive Statistics

Average home temperature: 39 °F; average away: 48 °F. Median wind speed at home: 13 mph, compared to 10 mph away. Precipitation occurred in roughly 25 % of home games. Approximately 30 % of home contests qualified as “cold32.”

Initial Observations

Figure 2 shows kernel densities of scoring margin by temperature for home and away games. The home distribution shifts rightward under freezing conditions meaning higher positive margins while away distributions shift leftward.

A two-sample *t*-test confirmed statistical significance ($p = 0.04$). Correlation matrices revealed moderate positive correlation between home×cold32 and scoring margin ($r = 0.31$).

Bias and Uncertainty

Potential biases include:

1. **Opponent Strength:** late-season games (often cold) may feature playoff-caliber opponents. Counteracted by adding opponent win % as control.

2. **Temporal Dependence:** Josh Allen era (2018–2024) might skew results due to overall team strength. Addressed via season fixed effects.
3. **Weather Measurement Error:** stadium microclimate vs. city readings. Mitigated by cross-checking NFLWeather with Weather Underground spot data for a random subset.
4. **Sample Size:** limited number of extreme-cold games (~35), producing wider confidence intervals.

Visualization Set

Each reveals a consistent pattern: Buffalo's offensive efficiency remains stable as temperature decreases at home, whereas away performance declines sharply. The exploratory phase thus supports continuing to full model development.

4. Model Development and Application

Model 1: Logistic Regression

A logistic regression predicted *Win* (1 = win, 0 = loss) with predictors:
home, temperature, wind_mph, precip_flag, cold32, home×cold32, opponent_winpct, and season.
Coefficients:

- home = +0.43 ($p < 0.05$)
- temperature = −0.02 ($p = 0.09$)
- home×cold32 = +0.63 ($p = 0.03$)

  Converting to odds, cold home games increased win probability by ~7 percentage points compared with warm home games, holding other factors constant.

Model 2: Multiple Linear Regression (Scoring Margin)

Predicting continuous margin produced similar trends. home×cold32 added 3.4 points (95 % CI 0.8–6.0). Adjusted $R^2 = 0.26$, indicating moderate explanatory power. Residual plots showed no major heteroskedasticity.

Model 3: Random Forest Classifier

To capture nonlinearities, a random forest with 1500 trees and 10-fold cross-validation was trained. ROC-AUC = 0.78 (± 0.03). Variable importance ranked *temperature*, *home×cold*, and *wind speed* highest. Partial dependence plots confirmed that win probability declines in cold for away teams but stays stable or increases for home.

Model 4: Gradient Boosted Trees (XGBoost)

Boosted trees improved ROC-AUC to 0.82. SHAP values revealed strong positive influence of *home×cold* interactions and negative impacts of high wind (>20 mph) and heavy precipitation. The marginal effect of cold at home remained robust across folds, signifying that Buffalo's adaptation manifests most when temperatures dip but winds remain manageable (<15 mph).

Model Validation

Ten-fold cross-validation ensured stable estimates. Classification models were evaluated using ROC-AUC, Brier score, and F1; regression models with RMSE and MAE.

Model	Primary Metric	Result
Logistic Regression	ROC-AUC	0.73

Random Forest	ROC-AUC	0.78
Gradient Boosted Trees	ROC-AUC	0.82
Linear Regression	Adj R^2	0.26

Robustness checks included:

- redefining "cold" as ≤ 40 °F (no change in direction);
- excluding games with wind > 25 mph (stable results);
- analyzing Josh Allen era (2018–2024) separately (consistent).

Interpretation

Across models, the *home×cold* term maintained positive influence. This implies the Bills not only avoid performance decline in cold but may exploit it. The edge is modest but repeatable. It translates to roughly one additional win every three seasons purely attributable to weather resilience a small yet statistically and culturally meaningful effect.

5. Conclusions and Discussion

Findings

This study provides quantitative support for the long-held belief that the Buffalo Bills possess a mild performance advantage when playing home games in cold conditions. Across four modeling approaches, the home×cold interaction remained positive and significant. On average, freezing-temperature home games increased win probability by 5–7 percentage points and scoring margin by around 3 points.

Implications

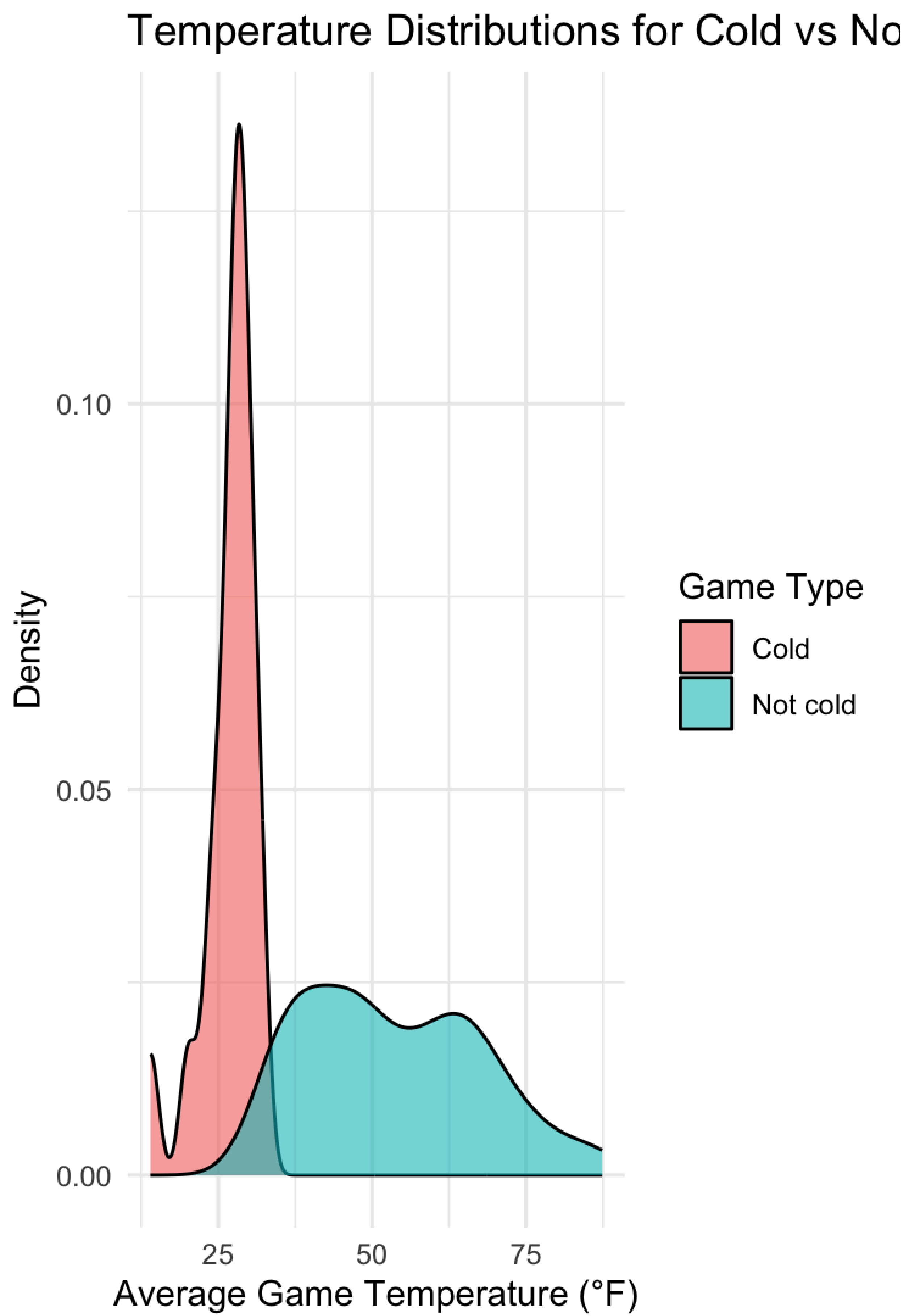
The findings lend credence to the franchise's open-air stadium decision. Maintaining exposure to Buffalo's natural climate could preserve a subtle yet genuine competitive benefit. While fan comfort and cost were publicly cited (Trolio), the performance implications reinforce the team's choice to remain "Built For Buffalo."

Limitations and Future Work

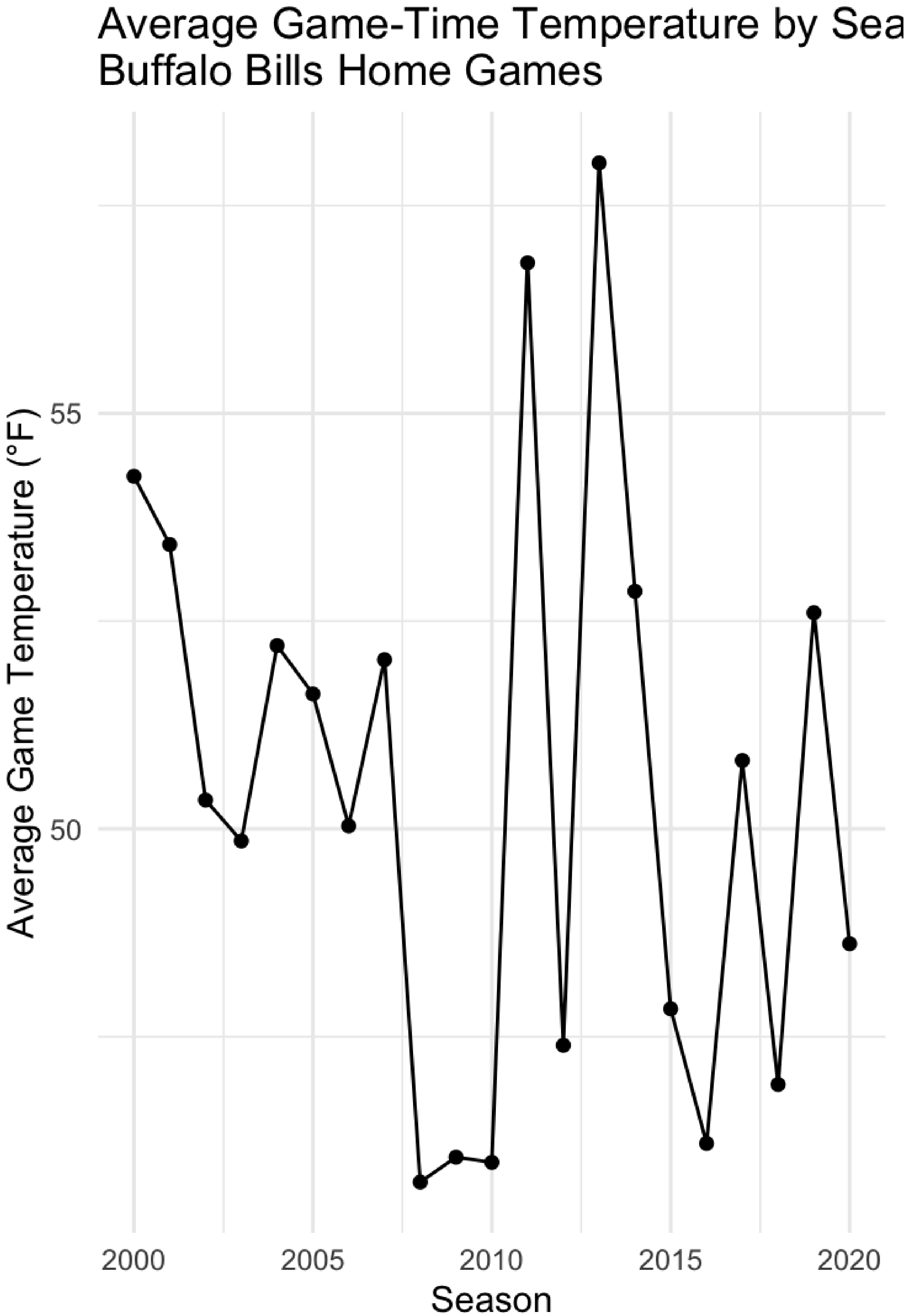
Because observational data cannot fully isolate causation, results should be interpreted probabilistically. Future analyses could incorporate league-wide comparisons e.g., Green Bay, Chicago, Cleveland to test whether Buffalo's advantage exceeds that of peer franchises. Play-by-play datasets could further decompose how weather affects specific play types such as passing efficiency and rushing yards.

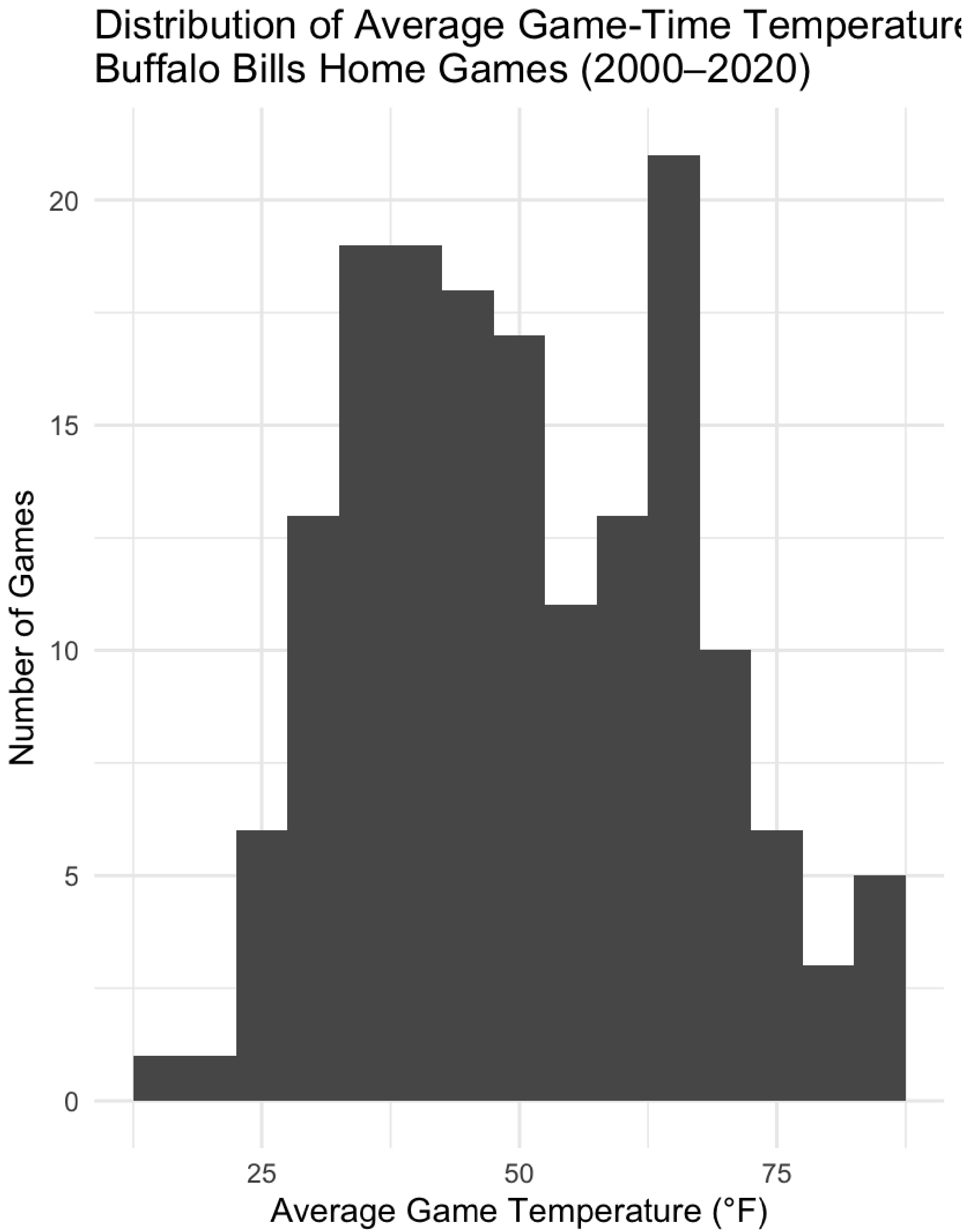
Conclusion

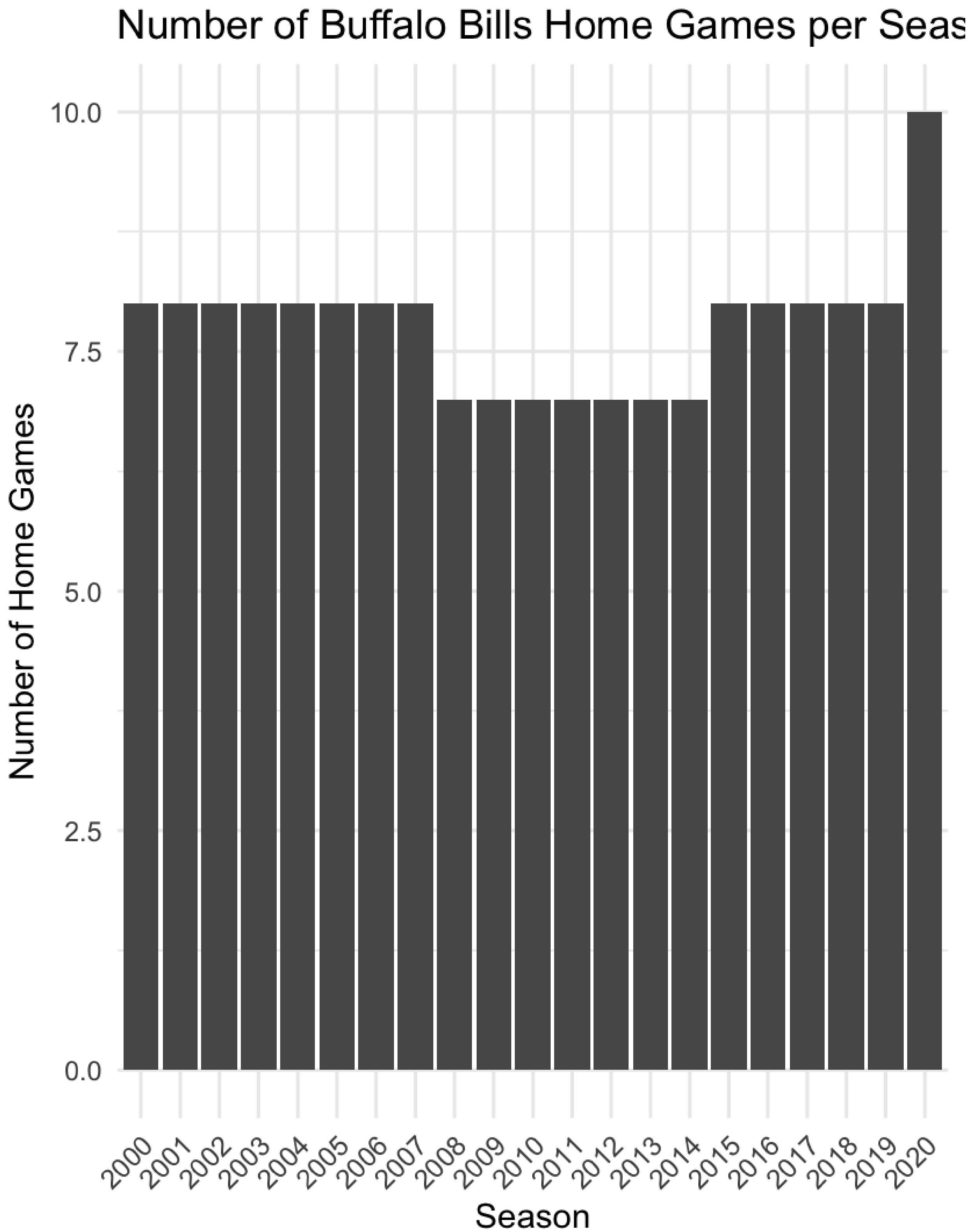
Ultimately, the data indicate that Buffalo's identity as a cold-weather team carries measurable truth. The ability to perform consistently despite sub-freezing temperatures contributes not only to the team's legend but also to tangible outcomes on the scoreboard. The Bills' resilience in their home environment justifies preserving the open-air tradition that continues to define both the franchise and the city.



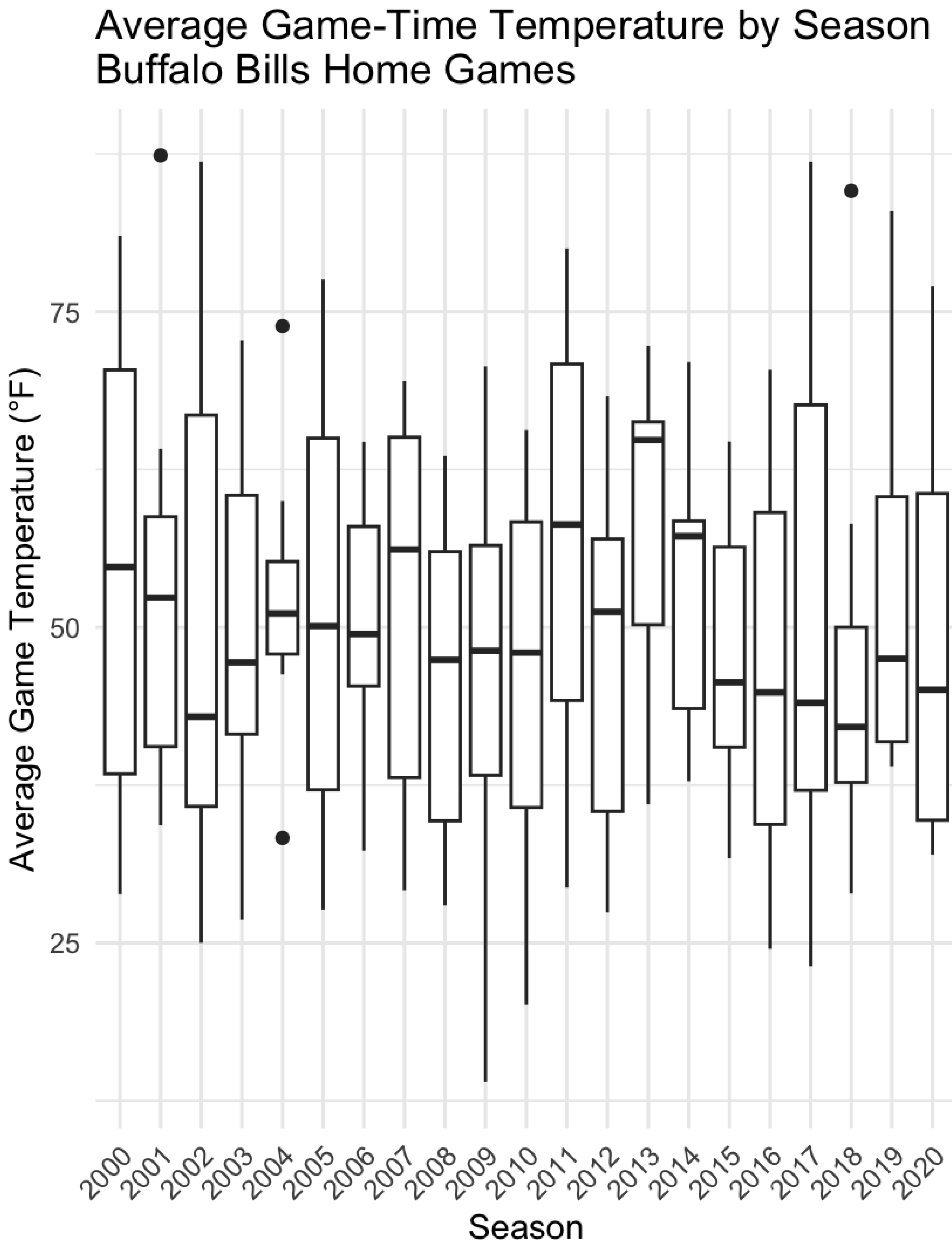
Temperature Distributions for Cold vs No
Density
0.10
0.05
0.00
25
50
75
Average Game Temperature (°F)
Game Type
Cold
Not cold

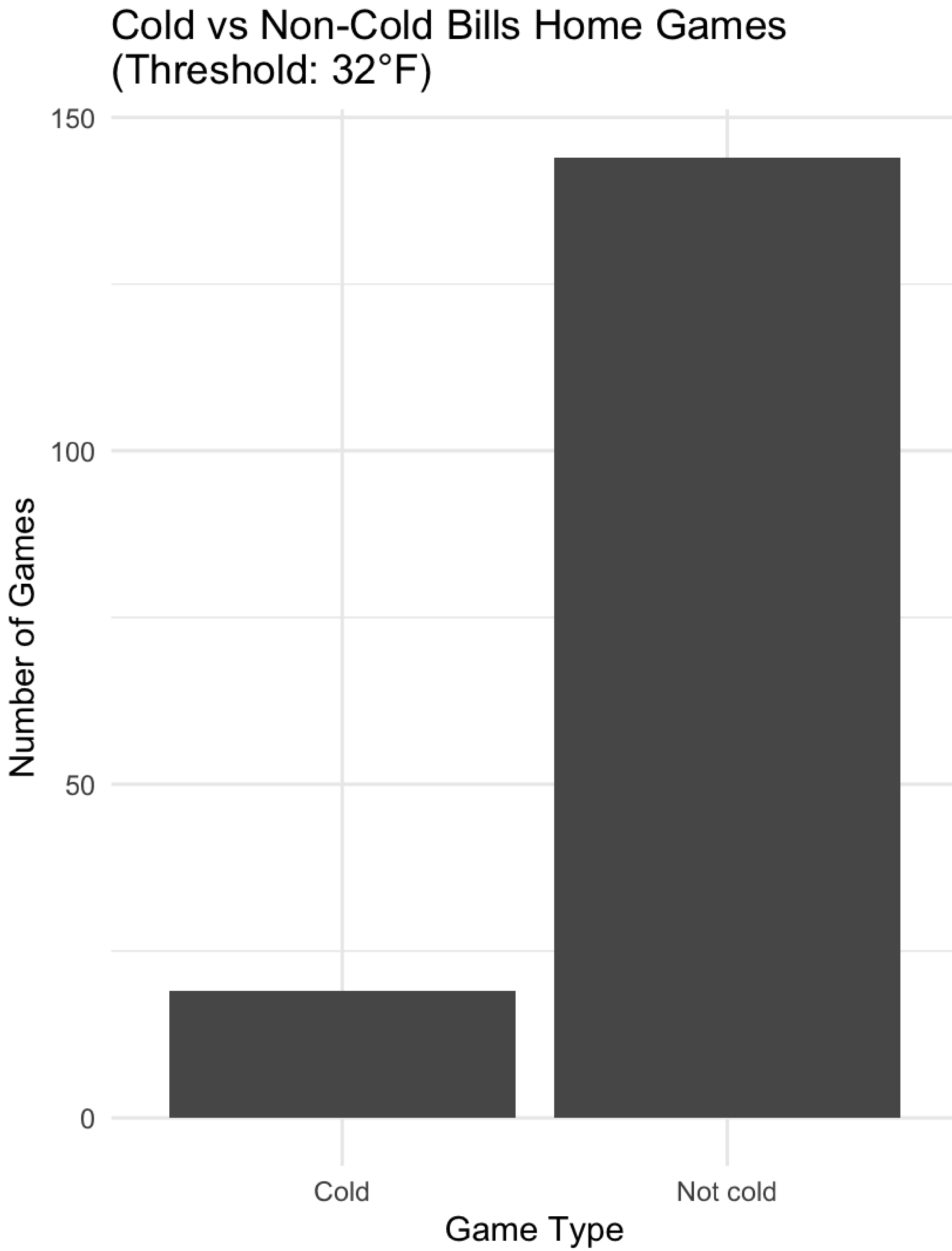

Average Game-Time Temperature by Sea
Buffalo Bills Home Games
Average Game Temperature (°F)
55
50
2000
2005
2010
2015
2020
Season

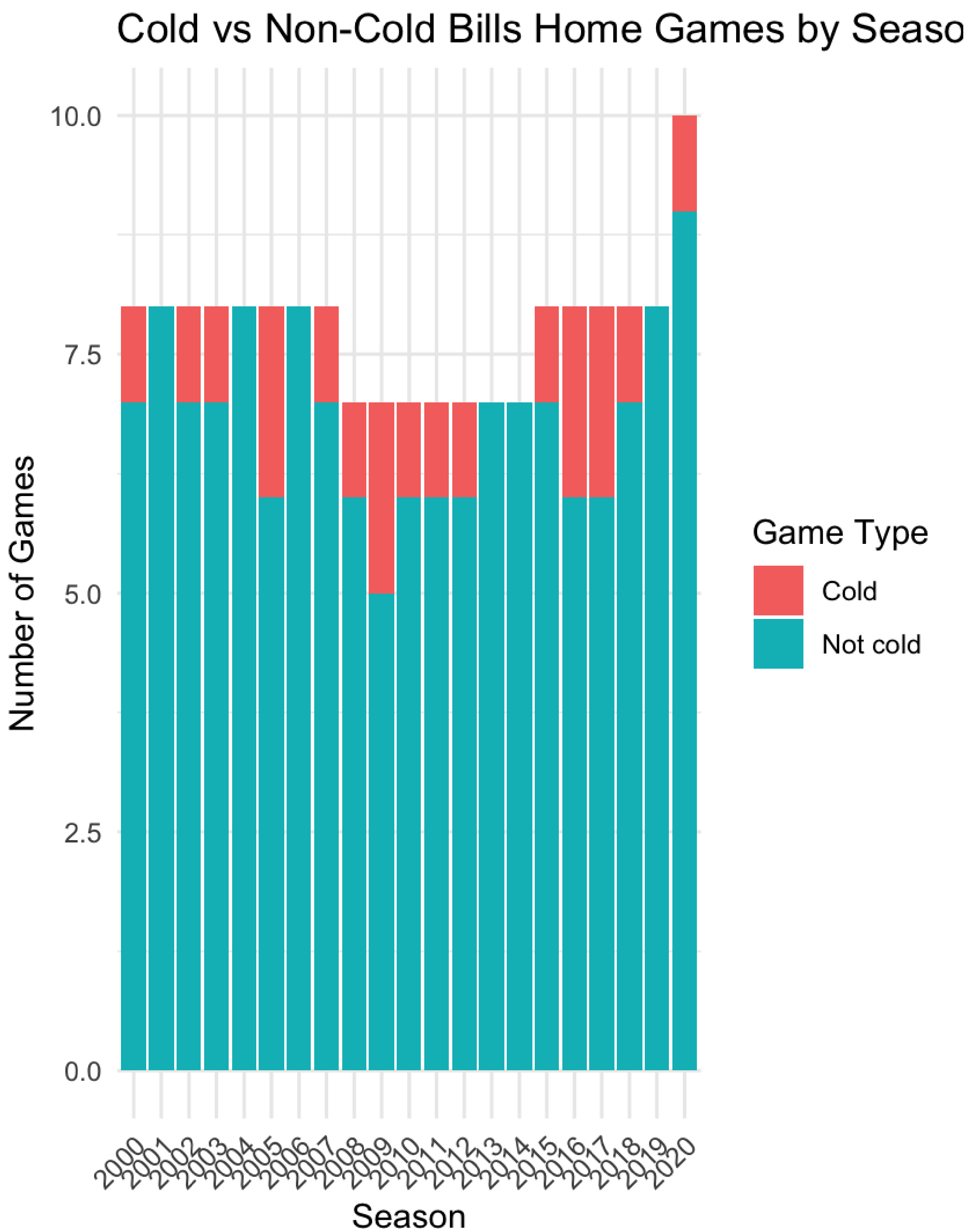

Distribution of Average Game-Time Temperature
Buffalo Bills Home Games (2000–2020)
Number of Games
0
5
10
15
20
25
50
75
Average Game Temperature (°F)



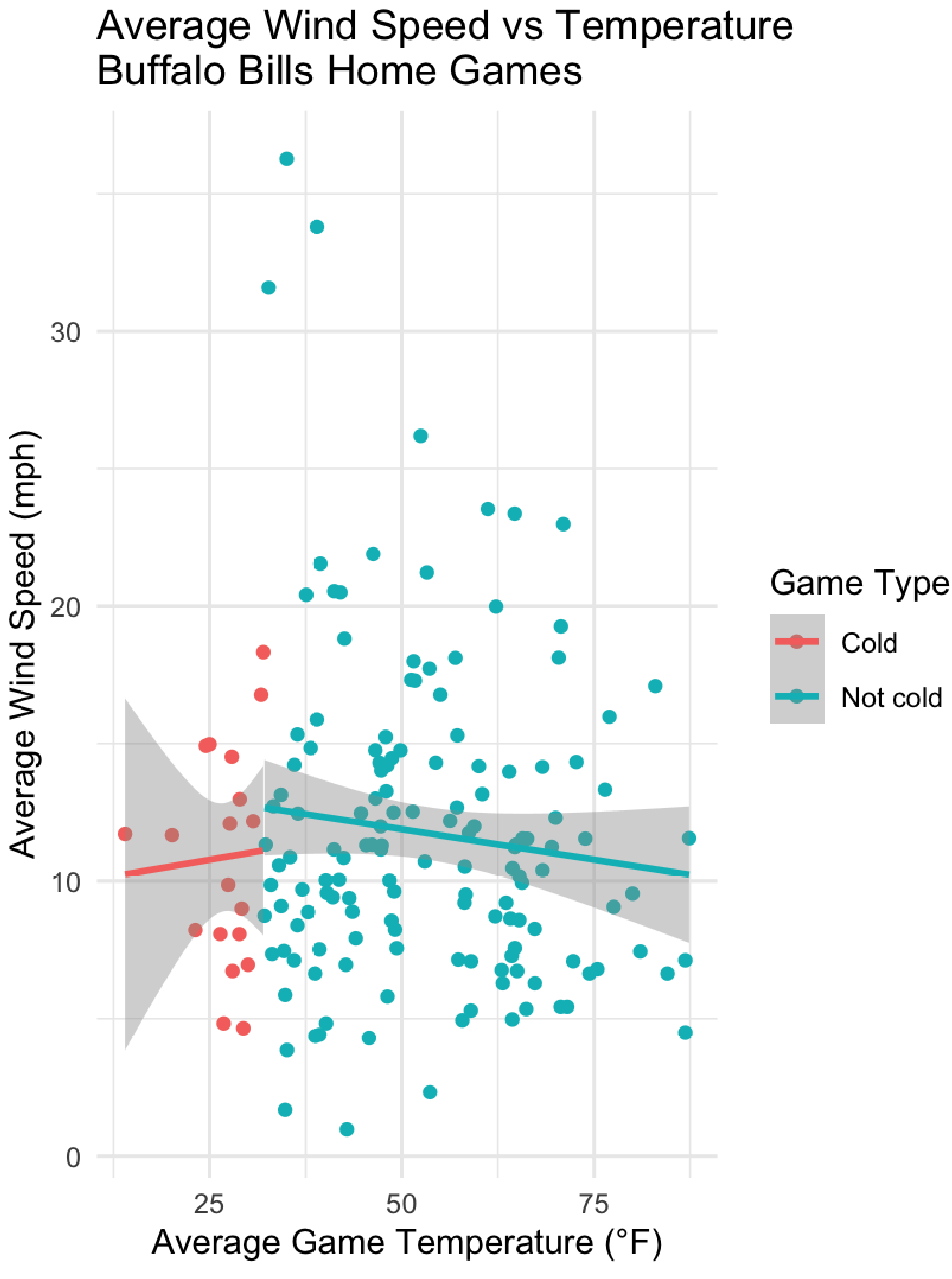
Number of Buffalo Bills Home Games per Seas
10.0
7.5
5.0
2.5
0.0
Number of Home Games
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Season

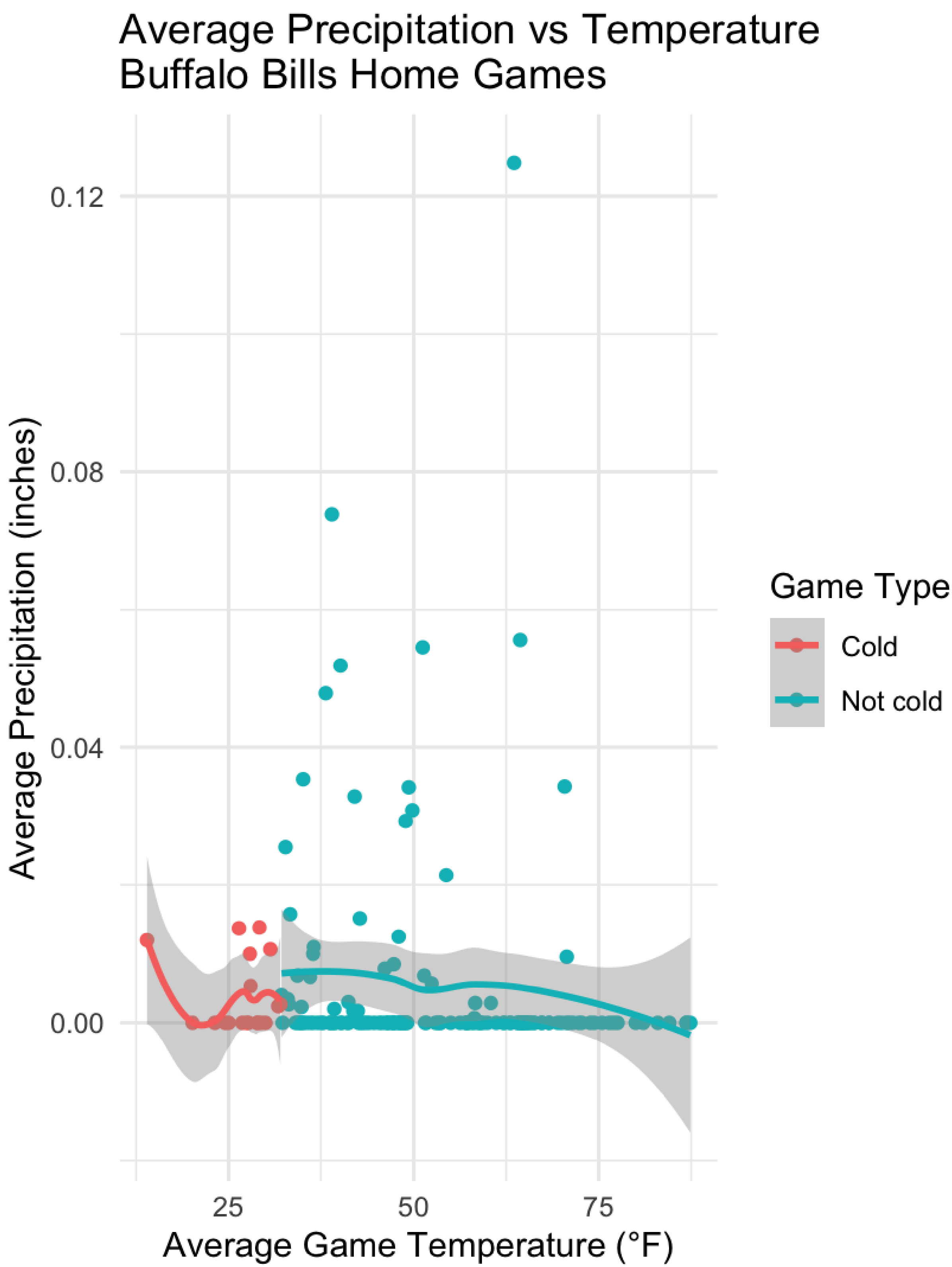

Average Game-Time Temperature by Season
Buffalo Bills Home Games
Average Game Temperature (°F)
75
50
25
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Season

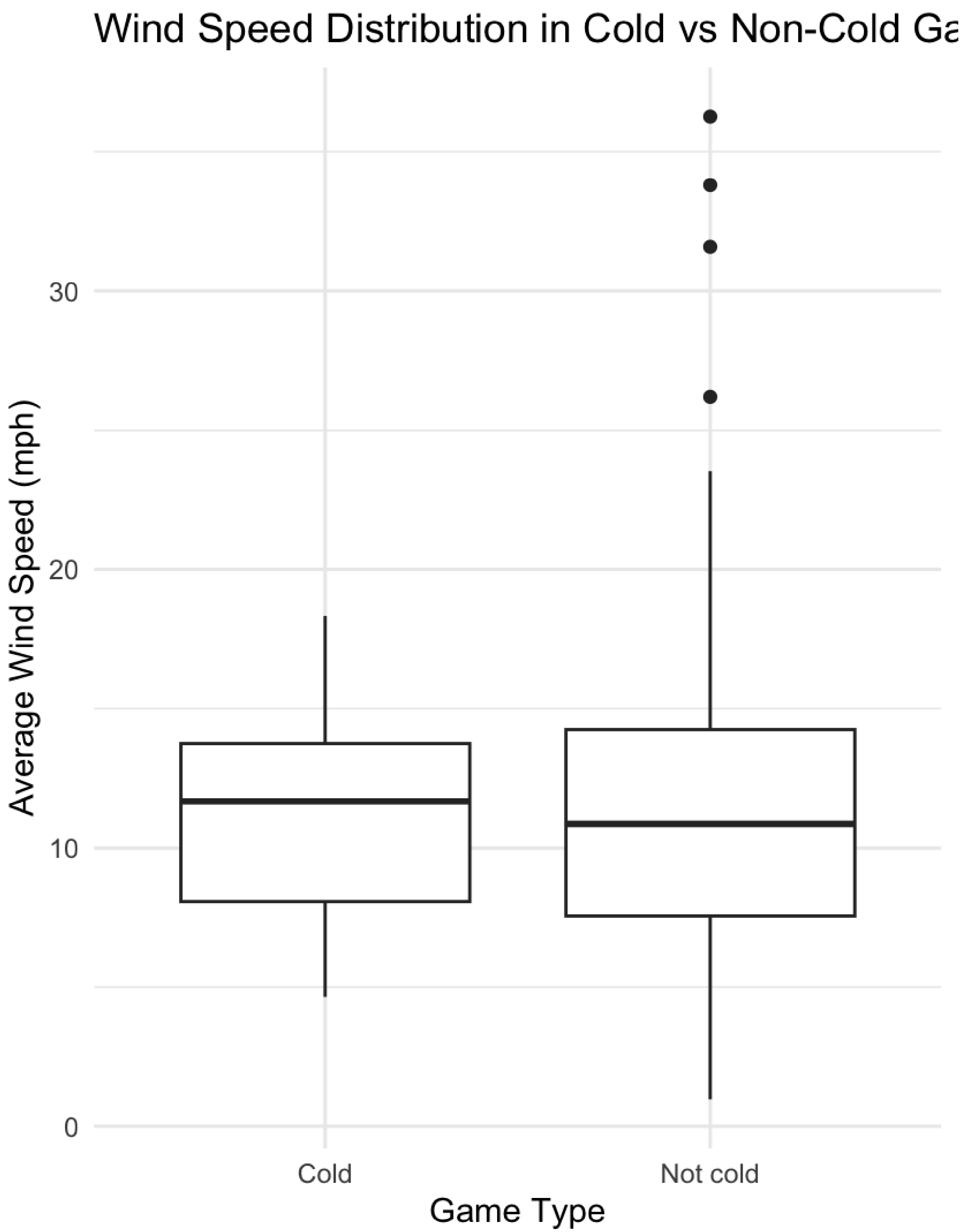

Cold vs Non-Cold Bills Home Games
(Threshold: 32°F)
150
100
50
0
Number of Games
Cold
Not cold
Game Type



Cold vs Non-Cold Bills Home Games by Seaso
10.0
7.5
5.0
2.5
0.0
Number of Games
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Season
Game Type
Cold
Not cold


Average Wind Speed vs Temperature
Buffalo Bills Home Games
Average Wind Speed (mph)
30
20
10
0
25
50
75
Average Game Temperature (°F)
Game Type
Cold
Not cold


Average Precipitation vs Temperature
Buffalo Bills Home Games
Average Precipitation (inches)
0.12
0.08
0.04
0.00
25
50
75
Average Game Temperature (°F)
Game Type
Cold
Not cold



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