```
import os
import json

import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

from sklearn.model_selection import train_test_split
from sklearn.linear_model import LinearRegression
from sklearn.ensemble import RandomForestRegressor
from sklearn.metrics import r2_score, mean_squared_error

# Beautiful global style
sns.set_theme(style="whitegrid", palette="viridis")


# ------------------------------------------------
# 1. FILE PATHS
# ------------------------------------------------

FILE_PATHS = {
    2019: "/Users/randalburks/Downloads/FALL 2025/482/final
project/play_by_play_2019.csv",
    2020: "/Users/randalburks/Downloads/FALL 2025/482/final
project/play_by_play_2020.csv",
    2021: "/Users/randalburks/Downloads/FALL 2025/482/final
project/play_by_play_2021.csv",
    2023: "/Users/randalburks/Downloads/FALL 2025/482/final
project/play_by_play_2023.csv",
}

BASE_DIR = os.path.dirname(next(iter(FILE_PATHS.values())))



# ------------------------------------------------
# 2. LOAD & CLEAN DATA
# ------------------------------------------------

def load_pbp_data(file_paths):
    tables = []
    for season, path in file_paths.items():
        print(f"Loading season {season} from {path} ...")
        df = pd.read_csv(path, low_memory=False)
        df["season"] = season
        tables.append(df)
    full_df = pd.concat(tables, ignore_index=True)
    print("Total rows:", len(full_df))
    return full_df
```

```python
def basic_cleaning(df):
    rename_map = {}
    if "total_home_score" in df and "home_score" not in df:
        rename_map["total_home_score"] = "home_score"
    if "total_away_score" in df and "away_score" not in df:
        rename_map["total_away_score"] = "away_score"

    df = df.rename(rename_map)

    keep_cols = [

"season","game_id","qtr","game_seconds_remaining","score_differential"
,
        "posteam","defteam","home_team","away_team",
        "home_score","away_score","epa","wpa"
    ]

    df = df[keep_cols].dropna()
    print("Rows after cleaning:", len(df))
    return df



# ------------------------------------------------
# 3. CLUTCH LABELING
# ------------------------------------------------

def add_clutch_flag(df):
    df["is_clutch"] = (
        (df["qtr"] == 4) &
        (df["game_seconds_remaining"] <= 5*60) &
        (df["score_differential"].abs() <= 8)
    )
    return df


def get_clutch_plays(df):
    clutch = df[df["is_clutch"] == True].copy()
    print("Clutch plays:", len(clutch))
    return clutch



# ------------------------------------------------
# 4. TEAM CLUTCH METRICS
# ------------------------------------------------

def build_team_clutch_stats(clutch_df):
    clutch_df["success"] = clutch_df["epa"] > 0
```

```
    grouped = clutch_df.groupby(["posteam","season"]).agg(
        clutch_plays_count=("game_id","count"),
        clutch_epa_avg=("epa","mean"),
        clutch_wpa_avg=("wpa","mean"),
        clutch_success_rate=("success","mean")
    ).reset_index().rename(columns={"posteam":"team"})

    print("Team clutch stats:", grouped.shape)
    return grouped



# ------------------------------------------------
# 5. TEAM WINS
# ------------------------------------------------

def compute_team_wins(df):
    last_play =
df.sort_values(["game_id","game_seconds_remaining"]).groupby("game_id"
).tail(1)

    def choose_winner(row):
        if row["home_score"] > row["away_score"]:
            return row["home_team"]
        elif row["away_score"] > row["home_score"]:
            return row["away_team"]
        return None

    last_play["winner"] = last_play.apply(choose_winner, axis=1)

    wins =
last_play.dropna(subset=["winner"]).groupby(["winner","season"]).size(
).reset_index(name="wins")
    wins = wins.rename(columns={"winner":"team"})
    print("Team wins:", wins.shape)
    return wins



# ------------------------------------------------
# 6. BASE MODEL — Wins ~ Clutch EPA
# ------------------------------------------------

def wins_model(team_clutch, team_wins):
    merged = pd.merge(team_clutch, team_wins, on=["team","season"],
how="left").fillna({"wins":0})

    X = merged[["clutch_epa_avg"]]
    y = merged["wins"]
```

```
    X_train, X_test, y_train, y_test = train_test_split(X, y,
test_size=0.3, random_state=42)
    model = LinearRegression().fit(X_train, y_train)
    y_pred = model.predict(X_test)

    print("\n=== MODEL: Wins ~ Clutch EPA ===")
    print("R²:", r2_score(y_test, y_pred))
    rmse = np.sqrt(mean_squared_error(y_test, y_pred))
    print("RMSE:", rmse)
    print("Slope:", model.coef_[0])
    print("Intercept:", model.intercept_)

    return merged, model



# ------------------------------------------------
# 7. ADVANCED PREDICTIVE MODEL
# ------------------------------------------------

def predictive_clutch_model(merged_stats, pbp_clean):
    overall_epa = pbp_clean.groupby("posteam")["epa"].mean()
    merged_stats["overall_epa"] =
merged_stats["team"].map(overall_epa)

    feature_cols = [
        "clutch_success_rate",
        "clutch_plays_count",
        "clutch_wpa_avg",
        "wins",
        "overall_epa"
    ]

    X = merged_stats[feature_cols]
    y = merged_stats["clutch_epa_avg"]

    X_train, X_test, y_train, y_test = train_test_split(
        X, y, test_size=0.3, random_state=42
    )

    model = RandomForestRegressor(n_estimators=300, random_state=42)
    model.fit(X_train, y_train)
    y_pred = model.predict(X_test)

    print("\n=== ADVANCED PREDICTION MODEL ===")
    print("Predicting Clutch EPA")
    print("R²:", r2_score(y_test, y_pred))
    print("RMSE:", np.sqrt(mean_squared_error(y_test, y_pred)))

    importance_df = pd.DataFrame({
```

```
        "Feature": feature_cols,
        "Importance": model.feature_importances_
    }).sort_values("Importance", ascending=False)

    print("\n=== FEATURE IMPORTANCE ===")
    display(importance_df)

    latest = merged_stats["season"].max()
    latest_df = merged_stats[merged_stats["season"] == latest].copy()

    latest_df["predicted_clutch_epa"] =
model.predict(latest_df[feature_cols])

    predicted_best = latest_df.sort_values("predicted_clutch_epa",
ascending=False).iloc[0]

    print("\n=== PREDICTED BEST CLUTCH TEAM ===")
    print("Team:", predicted_best["team"])
    print("Predicted Clutch EPA:",
predicted_best["predicted_clutch_epa"])

    return latest_df, model



# ------------------------------------------------
# 8. NO-SQL JSON OUTPUT
# ------------------------------------------------

def save_team_results_json(df):
    results = {}

    for _, row in df.iterrows():
        key = f"{row['team']}_{int(row['season'])}"
        results[key] = {
            "clutch_plays_count": int(row["clutch_plays_count"]),
            "clutch_epa_avg": float(row["clutch_epa_avg"]),
            "clutch_wpa_avg": float(row["clutch_wpa_avg"]),
            "clutch_success_rate": float(row["clutch_success_rate"]),
            "wins": int(row["wins"])
        }

    out_path = os.path.join(BASE_DIR, "team_clutch_stats.json")
    try:
        with open(out_path, "w") as f:
            json.dump(results, f, indent=2)
        print("Saved JSON.")
    except:
        print("JSON save skipped.")
```

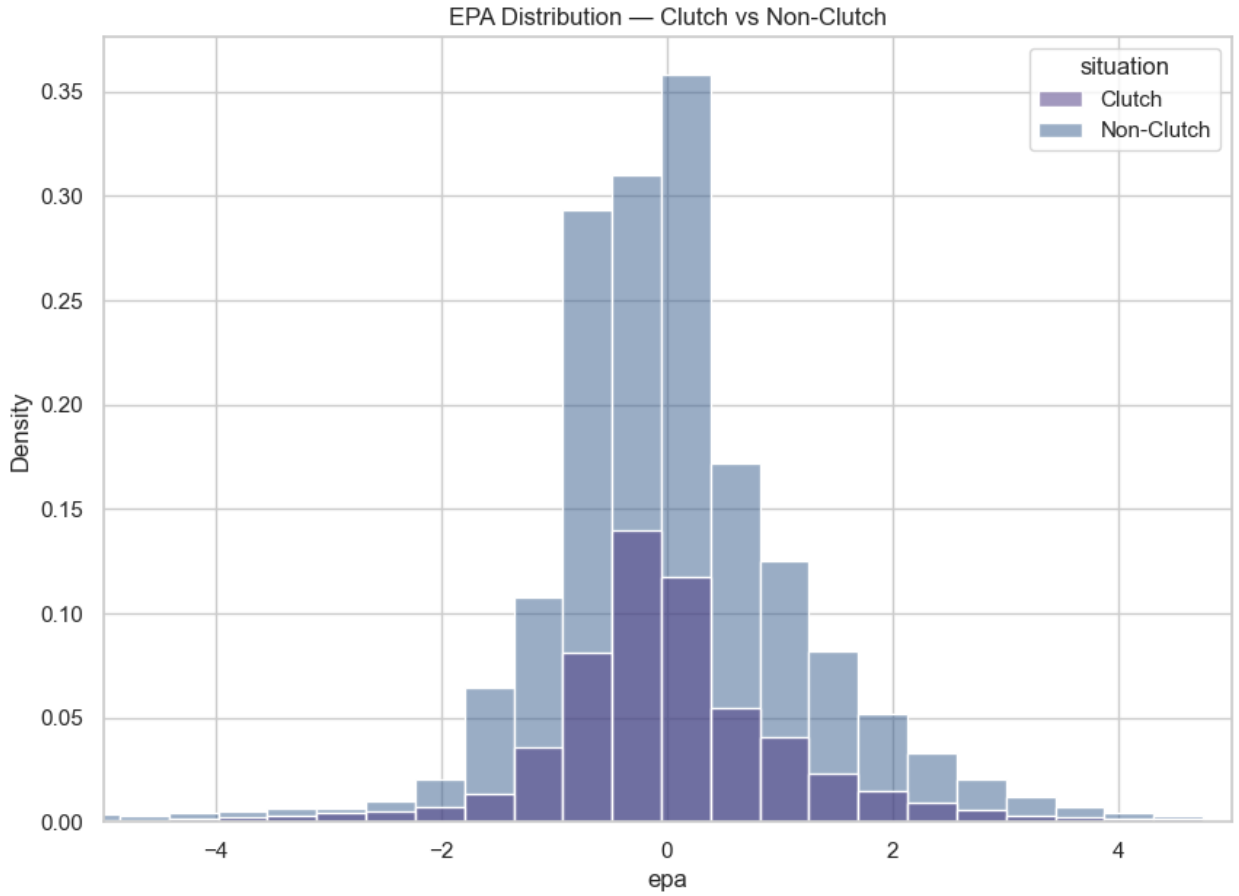
```
# ------------------------------------------------
# 9. BEAUTIFUL STORY PLOTS
# ------------------------------------------------

def make_story_plots(df, clutch_df, merged_stats):

    # EPA distribution clutch vs non
    non_clutch = df[~df["is_clutch"]]
    non_sample = non_clutch.sample(min(len(non_clutch),
len(clutch_df)*3), random_state=1)

    plot_df = pd.concat([
        clutch_df.assign(situation="Clutch")[["epa","situation"]],
        non_sample.assign(situation="Non-Clutch")[["epa","situation"]]
    ])

    plt.figure(figsize=(10,7))
    sns.histplot(plot_df, x="epa", hue="situation", bins=50,
stat="density", alpha=0.5)
    plt.xlim(-5,5)
    plt.title("EPA Distribution — Clutch vs Non-Clutch")
    plt.show()

    # Team ranking
    latest = merged_stats["season"].max()
    latest_df =
merged_stats[merged_stats["season"]==latest].sort_values("clutch_epa_a
vg")

    plt.figure(figsize=(10,8))
    sns.barplot(data=latest_df, x="clutch_epa_avg", y="team")
    plt.title(f"Clutch EPA by Team (Season {latest})")
    plt.show()

    # Clutch EPA vs Wins
    plt.figure(figsize=(8,6))
    sns.regplot(data=merged_stats, x="clutch_epa_avg", y="wins",
scatter_kws={"alpha":0.7})
    plt.title("Clutch EPA vs Wins")
    plt.show()



# ------------------------------------------------
# 10. EDA + IDA
# ------------------------------------------------

def eda_overview(df):
    print("===== HEAD =====")
```

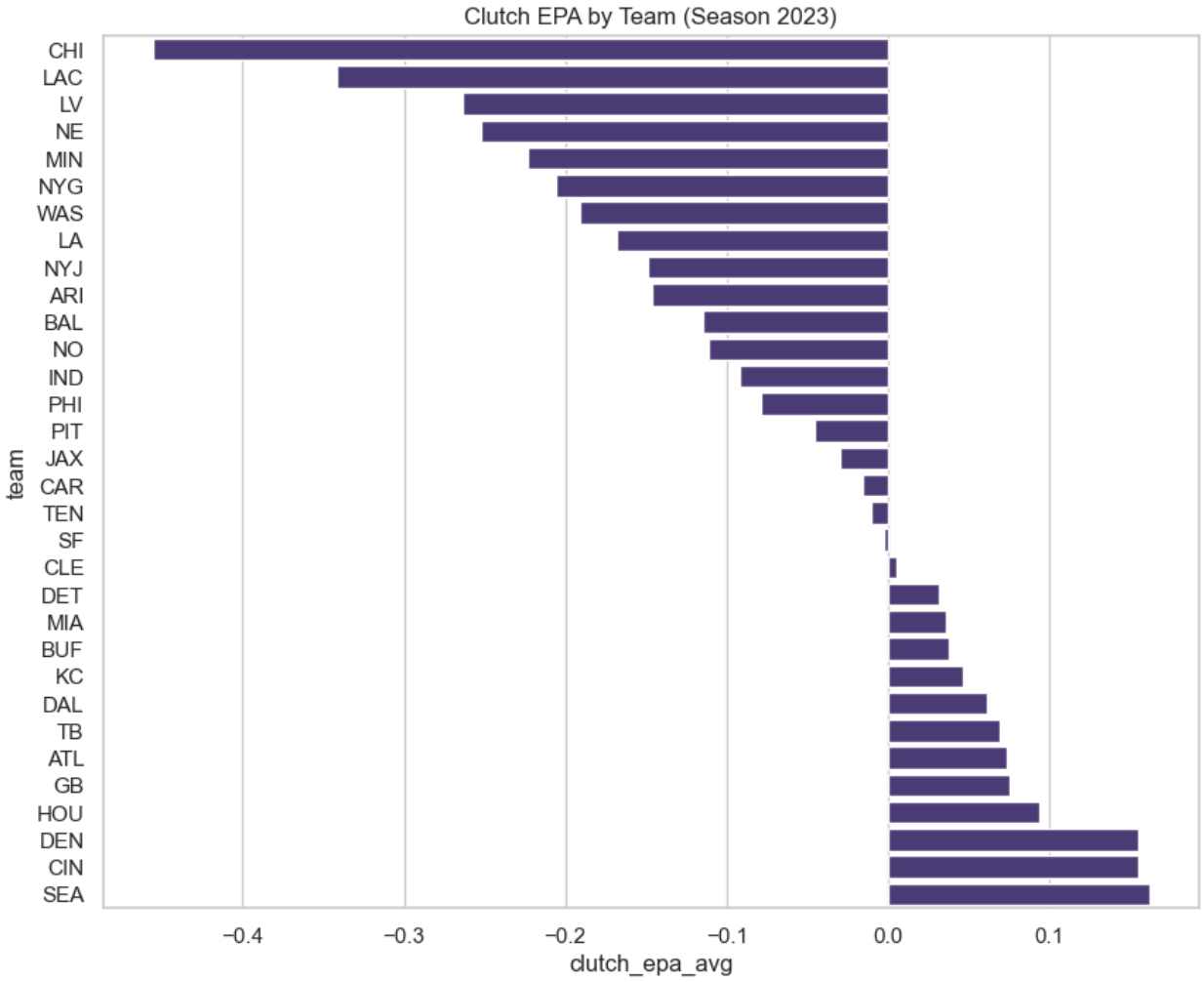
```
    display(df.head())
    print("\n===== SUMMARY =====")
    display(df.describe())
    print("\n===== MISSING VALUES =====")
    display(df.isnull().sum())


def ida_clutch_vs_nonclutch(df):
    clutch = df[df["is_clutch"]]
    non = df[~df["is_clutch"]]
    summary = pd.DataFrame({
        "Mean EPA": [clutch["epa"].mean(), non["epa"].mean()],
        "Std EPA":  [clutch["epa"].std(), non["epa"].std()],
        "Count":    [len(clutch), len(non)]
    }, index=["Clutch", "Non-Clutch"])

    print("===== CLUTCH VS NON-CLUTCH =====")
    display(summary)



def ida_team_level(merged_stats):
    pivot = merged_stats.pivot(index="team", columns="season",
values="clutch_epa_avg")

    plt.figure(figsize=(12,9))
    sns.heatmap(pivot, cmap="magma", center=0)
    plt.title("Clutch EPA Heatmap by Team & Season")
    plt.show()



# ------------------------------------------------
# 11. CLUTCH IMPROVEMENT SCORE
# ------------------------------------------------

def plot_clutch_improvement(df, merged_stats):
    overall = df.groupby("posteam")["epa"].mean()
    merged_stats["overall_epa"] = merged_stats["team"].map(overall)
    merged_stats["clutch_improvement"] =
merged_stats["clutch_epa_avg"] - merged_stats["overall_epa"]

    plt.figure(figsize=(10,8))
    sns.barplot(
        data=merged_stats.sort_values("clutch_improvement"),
        x="clutch_improvement", y="team", palette="viridis"
    )
    plt.title("Clutch EPA Improvement (Clutch EPA – Overall EPA)")
    plt.show()
```

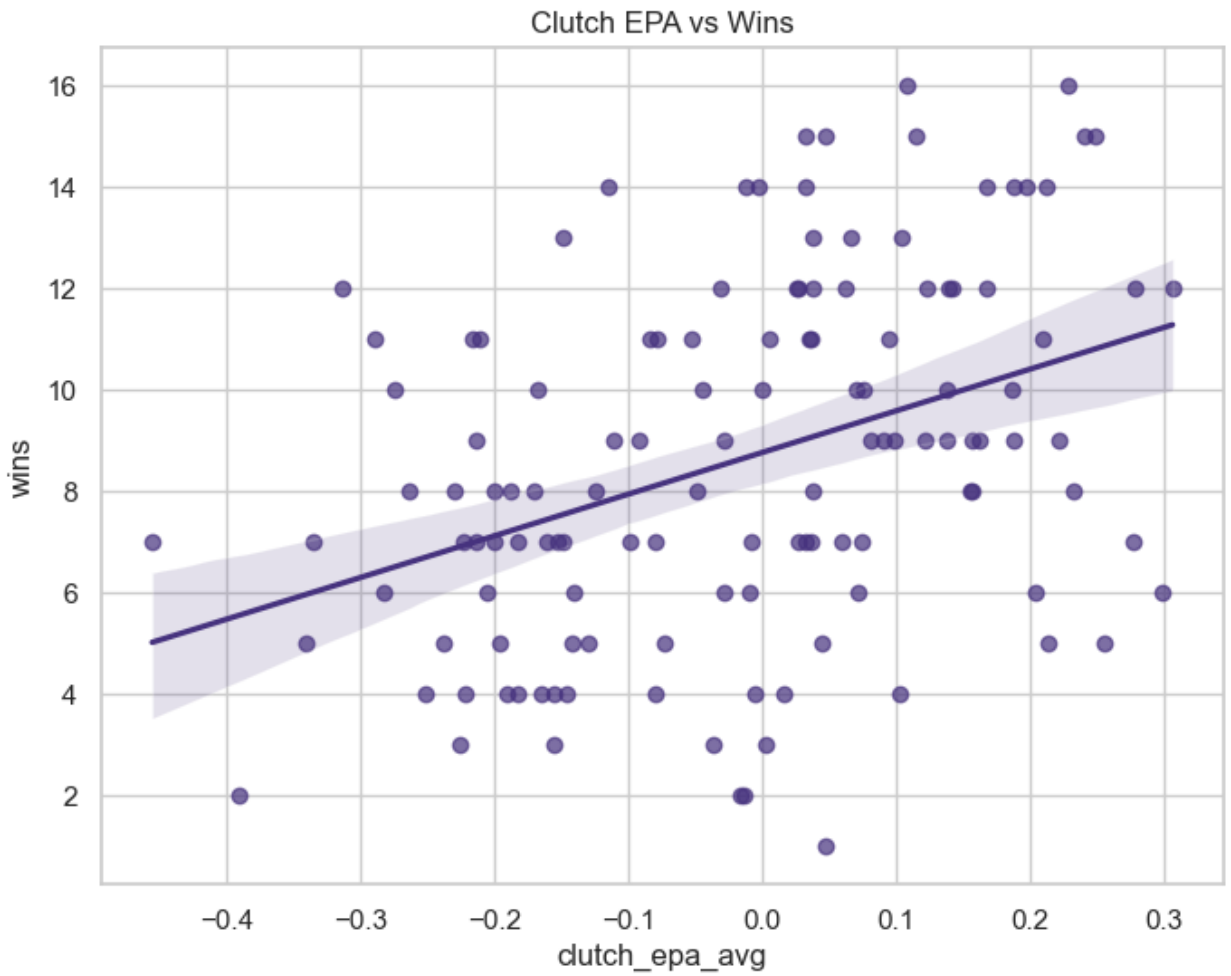
```python
# ------------------------------------------------
# 12. ACTUAL BEST CLUTCH TEAM (From real data)
# ------------------------------------------------

def find_best_clutch_team(merged_stats):
    latest = merged_stats["season"].max()
    latest_df = merged_stats[merged_stats["season"]==latest]
    best = latest_df.sort_values("clutch_epa_avg",
ascending=False).iloc[0]

    print("\n===== BEST CLUTCH TEAM (REAL DATA) =====")
    print("Team:", best["team"])
    print("Clutch EPA:", best["clutch_epa_avg"])
    print("Success Rate:", best["clutch_success_rate"])
    return best["team"]



# ------------------------------------------------
# 13. MAIN PIPELINE
# ------------------------------------------------

def main():
    pbp = load_pbp_data(FILE_PATHS)
    pbp_clean = basic_cleaning(pbp)
    pbp_clean = add_clutch_flag(pbp_clean)

    clutch_plays = get_clutch_plays(pbp_clean)

    team_clutch = build_team_clutch_stats(clutch_plays)
    team_wins = compute_team_wins(pbp_clean)

    merged_stats, base_model = wins_model(team_clutch, team_wins)

    save_team_results_json(merged_stats)
    make_story_plots(pbp_clean, clutch_plays, merged_stats)

    eda_overview(pbp_clean)
    ida_clutch_vs_nonclutch(pbp_clean)
    ida_team_level(merged_stats)
    plot_clutch_improvement(pbp_clean, merged_stats)

    best_real = find_best_clutch_team(merged_stats)
    print("\nReal Best Clutch Team:", best_real)

    predicted_df, advanced_model =
predictive_clutch_model(merged_stats, pbp_clean)
    predicted_best = predicted_df.sort_values("predicted_clutch_epa",
ascending=False).iloc[0]["team"]
```

```
    print("\nPredicted Best Clutch Team:", predicted_best)

# RUN EVERYTHING
main()
```

```
Loading season 2019 from /Users/randalburks/Downloads/FALL
2025/482/final project/play_by_play_2019.csv ...
Loading season 2020 from /Users/randalburks/Downloads/FALL
2025/482/final project/play_by_play_2020.csv ...
Loading season 2021 from /Users/randalburks/Downloads/FALL
2025/482/final project/play_by_play_2021.csv ...
Loading season 2023 from /Users/randalburks/Downloads/FALL
2025/482/final project/play_by_play_2023.csv ...
Total rows: 194552
Rows after cleaning: 181295
Clutch plays: 9894
Team clutch stats: (128, 6)
Team wins: (128, 3)

=== MODEL: Wins ~ Clutch EPA ===
R²: 0.017253156547390236
RMSE: 3.286611588293964
Slope: 9.501049206676011
Intercept: 8.872312359096965
Saved JSON.
```


EPA Distribution — Clutch vs Non-Clutch
situation
Clutch
Non-Clutch
Density
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
−4
−2
0
2
4
epa

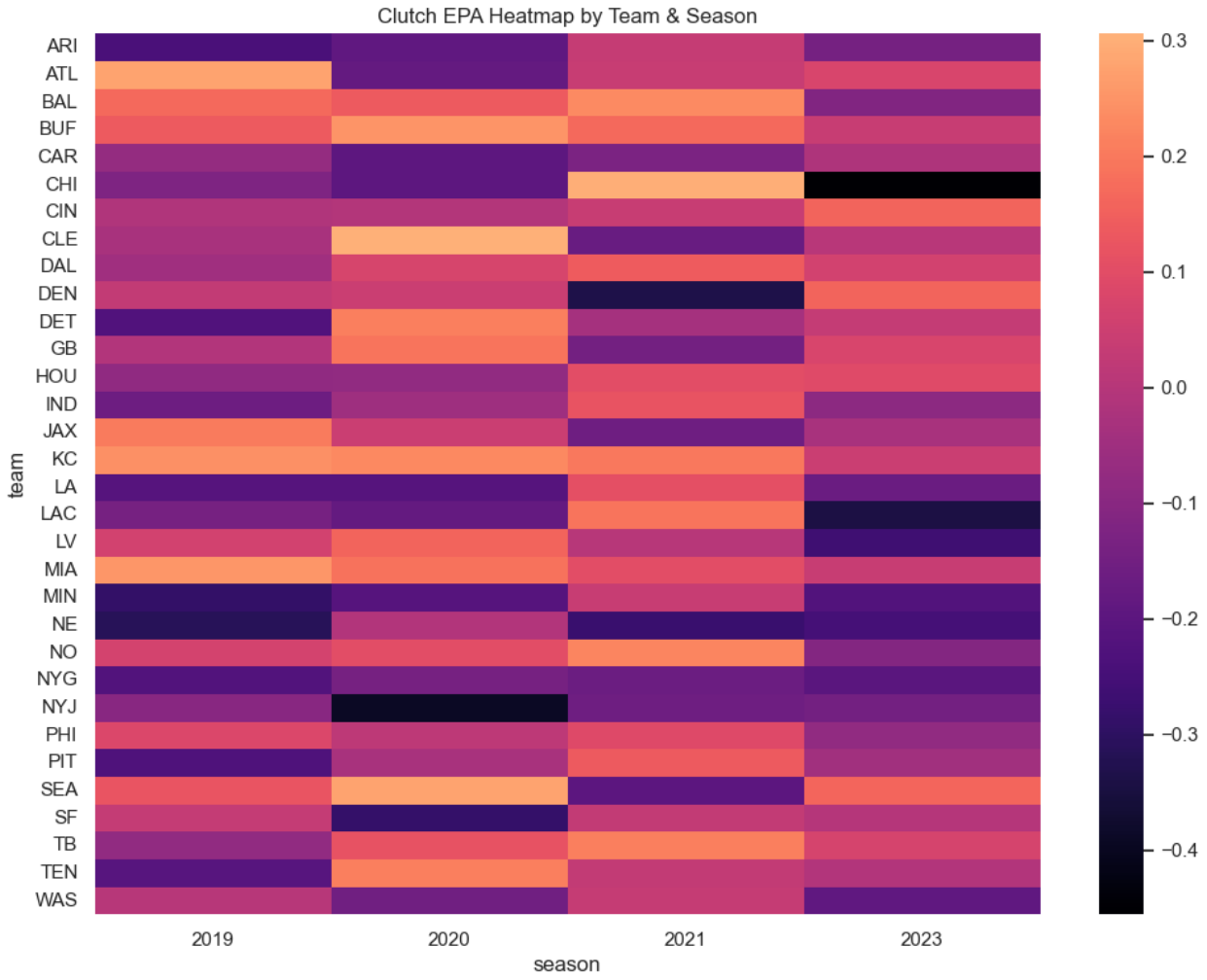

Clutch EPA by Team (Season 2023)
team
CHI
LAC
LV
NE
MIN
NYG
WAS
LA
NYJ
ARI
BAL
NO
IND
PHI
PIT
JAX
CAR
TEN
SF
CLE
DET
MIA
BUF
KC
DAL
TB
ATL
GB
HOU
DEN
CIN
SEA
−0.4
−0.3
−0.2
−0.1
0.0
0.1
clutch_epa_avg



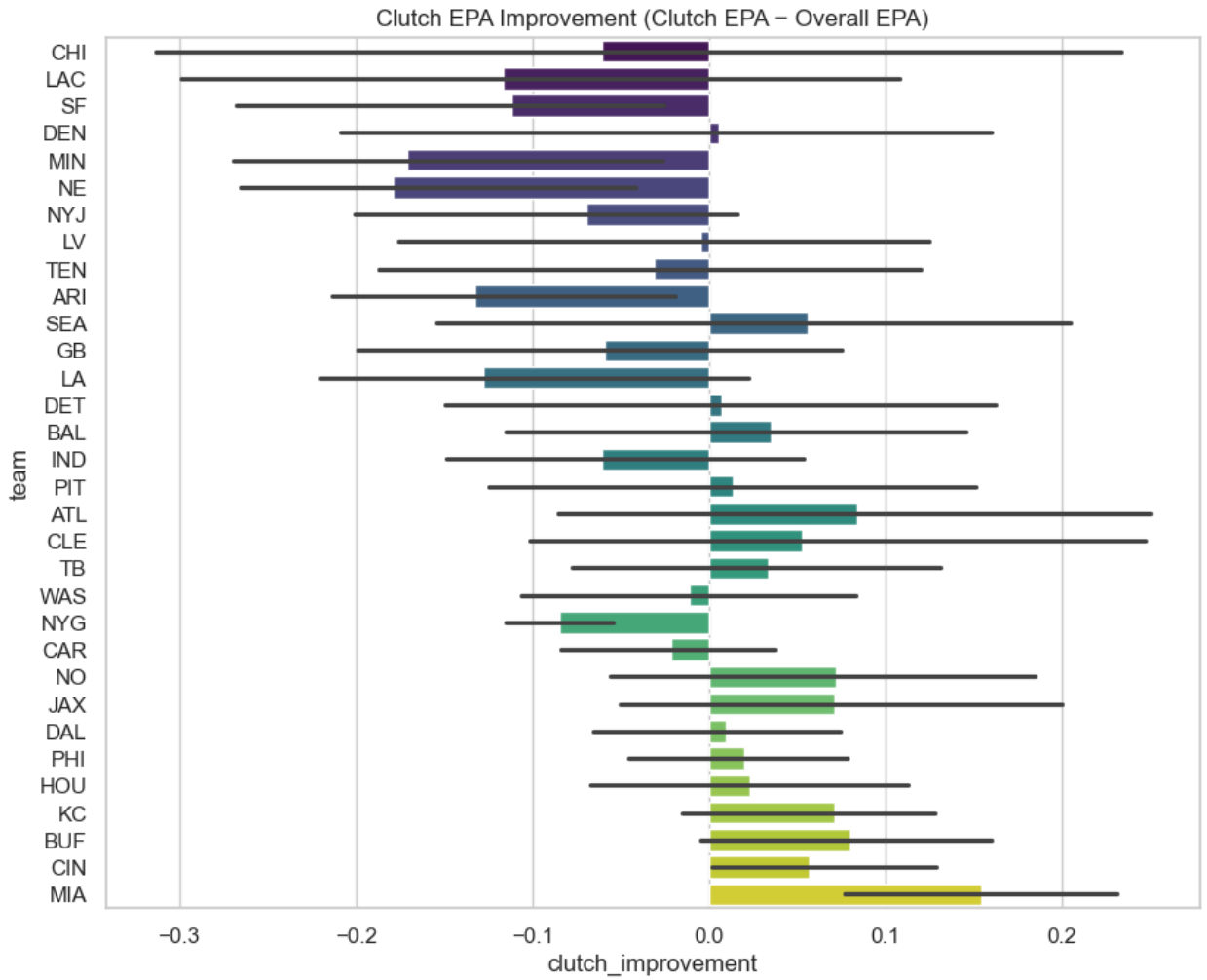

```
===== HEAD =====

   season          game_id  qtr  game_seconds_remaining
score_differential  \
1    2019  2019_01_ATL_MIN    1                  3600.0
0.0
2    2019  2019_01_ATL_MIN    1                  3600.0
0.0
3    2019  2019_01_ATL_MIN    1                  3560.0
0.0
4    2019  2019_01_ATL_MIN    1                  3521.0
0.0
5    2019  2019_01_ATL_MIN    1                  3479.0
0.0

  posteam defteam home_team away_team  home_score  away_score
epa  \
1     ATL     MIN       MIN       ATL          28          12
0.000000
2     ATL     MIN       MIN       ATL          28          12 -
```

```
1.658763
3     ATL     MIN       MIN       ATL          28          12 -
0.538914
4     ATL     MIN       MIN       ATL          28          12
0.142138
5     ATL     MIN       MIN       ATL          28          12 -
4.034299

        wpa  is_clutch
1  0.000000      False
2 -0.035015      False
3 -0.018435      False
4  0.018007      False
5 -0.113866      False


===== SUMMARY =====

               season            qtr  game_seconds_remaining  \
count  181295.000000  181295.000000            181295.00000
mean     2020.779122       2.540434              1745.19006
std         1.479901       1.124586              1041.55892
min      2019.000000       1.000000                 0.00000
25%      2020.000000       2.000000               855.00000
50%      2021.000000       2.000000              1803.00000
75%      2023.000000       4.000000              2641.00000
max      2023.000000       5.000000              3600.00000

       score_differential     home_score     away_score            epa
\
count       181295.000000  181295.000000  181295.000000  181295.000000

mean            -1.459902      23.959833      22.736330      -0.002938

std             10.696310      10.132413      10.052614       1.295115

min            -56.000000       0.000000       0.000000     -13.584859

25%             -7.000000      17.000000      16.000000      -0.581829

50%              0.000000      24.000000      23.000000      -0.034859

75%              4.000000      30.000000      30.000000       0.590608

max             55.000000      70.000000      59.000000       8.882384


                wpa
count  181295.000000
mean        0.000845
std         0.040171
```

```
min         -0.737291
25%         -0.014271
50%         -0.000019
75%          0.011980
max          0.944656


===== MISSING VALUES =====

season                    0
game_id                   0
qtr                       0
game_seconds_remaining    0
score_differential        0
posteam                   0
defteam                   0
home_team                 0
away_team                 0
home_score                0
away_score                0
epa                       0
wpa                       0
is_clutch                 0
dtype: int64

===== CLUTCH VS NON-CLUTCH =====

             Mean EPA   Std EPA   Count
Clutch     -0.014367  1.245143    9894
Non-Clutch -0.002279  1.297942  171401
```




```
/var/folders/j9/y9drl51s2gvbm203cbmk7py80000gn/T/
ipykernel_71478/2222944035.py:324: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be
removed in v0.14.0. Assign the `y` variable to `hue` and set
`legend=False` for the same effect.

  sns.barplot(
```




```
===== BEST CLUTCH TEAM (REAL DATA) =====
Team: SEA
Clutch EPA: 0.1619354368476224
Success Rate: 0.4807692307692308

Real Best Clutch Team: SEA

=== ADVANCED PREDICTION MODEL ===
Predicting Clutch EPA
R²: 0.8126171716994586
RMSE: 0.07263050895451344

=== FEATURE IMPORTANCE ===

                Feature  Importance
2       clutch_wpa_avg    0.754805
0  clutch_success_rate    0.139277
1   clutch_plays_count    0.046034
```

```
4          overall_epa    0.039720
3                 wins    0.020164


=== PREDICTED BEST CLUTCH TEAM ===
Team: SEA
Predicted Clutch EPA: 0.12703221419364158

Predicted Best Clutch Team: SEA
```