# IE6600 Project 2

Group2:

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In [ ]:
```
import pandas as pd
import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt
from datetime import datetime
from scipy.stats import pearsonr, spearmanr
```

## 1) Data import and Inspection

In [ ]:
```
df = pd.read_csv('VSRR_Provisional_Drug_Overdose_Death_Counts.csv')
```

In [ ]:
```
print(f"Dataset shape: {df.shape}")
print(f"Time period: {df['Year'].min()} - {df['Year'].max()}")
print(f"Geographic coverage: {df['State'].nunique()} states/territories")
print(f"Drug indicators: {df['Indicator'].nunique()} different types")
```

```
Dataset shape: (56243, 12)
Time period: 2015 - 2024
Geographic coverage: 41 states/territories
Drug indicators: 13 different types
```

In [ ]:
```
print(df.info())
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 56243 entries, 0 to 56242
Data columns (total 12 columns):
 #   Column                          Non-Null Count  Dtype  
---  ------                          --------------  -----  
 0   State                           56243 non-null  object 
 1   Year                            56243 non-null  int64  
 2   Month                           56243 non-null  object 
 3   Period                          56243 non-null  object 
 4   Indicator                       56243 non-null  object 
 5   Data Value                      43777 non-null  float64
 6   Percent Complete                56242 non-null  float64
 7   Percent Pending Investigation   56242 non-null  float64
 8   State Name                      56242 non-null  object 
 9   Footnote                        56242 non-null  object 
 10  Footnote Symbol                 56242 non-null  object 
 11  Predicted Value                 34226 non-null  float64
dtypes: float64(4), int64(1), object(7)
memory usage: 5.1+ MB
None
```

In [ ]:
```
print(df.head())
```

```
  State  Year     Month           Period        Indicator  Data Value  \
0    AK  2015   January  12 month-ending  Cocaine (T40.5)         NaN
1    AK  2015  February  12 month-ending  Cocaine (T40.5)         NaN
2    AK  2015     March  12 month-ending  Cocaine (T40.5)         NaN
3    AK  2015     April  12 month-ending  Cocaine (T40.5)         NaN
4    AK  2015       May  12 month-ending  Cocaine (T40.5)         NaN

   Percent Complete  Percent Pending Investigation State Name  \
0             100.0                            0.0     Alaska
1             100.0                            0.0     Alaska
2             100.0                            0.0     Alaska
3             100.0                            0.0     Alaska
4             100.0                            0.0     Alaska

                                            Footnote Footnote Symbol  \
0  Numbers may differ from published reports usin...              **
1  Numbers may differ from published reports usin...              **
2  Numbers may differ from published reports usin...              **
3  Numbers may differ from published reports usin...              **
4  Numbers may differ from published reports usin...              **

   Predicted Value
0              NaN
1              NaN
2              NaN
3              NaN
4              NaN
```

In [ ]:
```
for i, indicator in enumerate(df['Indicator'].unique(), 1):
    print(f"{i:2d}. {indicator}")
```

```
 1. Cocaine (T40.5)
 2. Heroin (T40.1)
 3. Methadone (T40.3)
 4. Natural & semi-synthetic opioids (T40.2)
 5. Natural & semi-synthetic opioids, incl. methadone (T40.2, T40.3)
 6. Natural, semi-synthetic, & synthetic opioids, incl. methadone (T40.2-T40.4)
 7. Number of Deaths
 8. Number of Drug Overdose Deaths
 9. Opioids (T40.0-T40.4,T40.6)
10. Percent with drugs specified
11. Psychostimulants with abuse potential (T43.6)
12. Synthetic opioids, excl. methadone (T40.4)
13. Numbe
```

### Insights:

- The data set contains 75600 rows and 12 Columns.
- The data spans between 2015 to 2024.
- The data contains data of 54 states with 12 different type of drug indicators.
- All the rows have a data type of either object or int.

## 2) Data cleaning and Prep:

In [ ]:
```
print("Missing values per column:")
missing_info = df.isnull().sum()
print(missing_info[missing_info > 0])
```

```
Missing values per column:
Data Value                        12466
Percent Complete                      1
Percent Pending Investigation         1
State Name                            1
Footnote                              1
Footnote Symbol                       1
Predicted Value                   22017
dtype: int64
```

In [ ]:
```
df['Date'] = pd.to_datetime(df['Year'].astype(str) + '-' + df['Month'], format='
```

In [ ]:
```
def categorize_drug(indicator):
    if 'Number of Deaths' in indicator or 'Number of Drug Overdose Deaths' in in
        return 'Total Deaths'
    elif 'Percent' in indicator:
        return 'Data Quality'
    elif 'Cocaine' in indicator:
        return 'Cocaine'
    elif 'Heroin' in indicator:
        return 'Heroin'
    elif 'Synthetic opioids' in indicator:
        return 'Synthetic Opioids'
    elif 'Natural & semi-synthetic opioids' in indicator and 'methadone' not in
        return 'Natural Opioids'
    elif 'Methadone' in indicator:
        return 'Methadone'
    elif 'Psychostimulants' in indicator:
        return 'Psychostimulants'
    elif 'Opioids' in indicator:
        return 'All Opioids'
    else:
        return 'Other'

df['Drug_Category'] = df['Indicator'].apply(categorize_drug)
```

In [ ]:
```
def get_region(state):
    northeast = ['CT', 'ME', 'MA', 'NH', 'NJ', 'NY', 'PA', 'RI', 'VT']
    midwest = ['IL', 'IN', 'IA', 'KS', 'MI', 'MN', 'MO', 'NE', 'ND', 'OH', 'SD',
    south = ['AL', 'AR', 'DE', 'FL', 'GA', 'KY', 'LA', 'MD', 'MS', 'NC', 'OK', '
    west = ['AK', 'AZ', 'CA', 'CO', 'HI', 'ID', 'MT', 'NV', 'NM', 'OR', 'UT', 'W

    if state in northeast:
        return 'Northeast'
    elif state in midwest:
        return 'Midwest'
    elif state in south:
        return 'South'
    elif state in west:
        return 'West'
    else:
        return 'Other'

df['Region'] = df['State'].apply(get_region)
```

In [ ]:
```
df_main = df[df['Drug_Category'] != 'Data Quality'].copy()
```

In [ ]:
```
def get_season(month):
    if month in ['December', 'January', 'February']:
        return 'Winter'
    elif month in ['March', 'April', 'May']:
        return 'Spring'
    elif month in ['June', 'July', 'August']:
        return 'Summer'
    else:
        return 'Fall'

df_main['Season'] = df_main['Month'].apply(get_season)
```

In [ ]:
```
print(f"Main analysis dataset: {df_main.shape[0]} rows")
print(f"Drug categories: {df_main['Drug_Category'].unique()}")
print(f"Regions: {df_main['Region'].unique()}")
```

```
Main analysis dataset: 51443 rows
Drug categories: ['Cocaine' 'Heroin' 'Methadone' 'Natural Opioids' 'Other' 'Total
Deaths'
 'All Opioids' 'Psychostimulants' 'Synthetic Opioids']
Regions: ['West' 'South' 'Northeast' 'Other' 'Midwest']
```

### Insights:

- Of the 75600 Data points there are 14072 Missing values.
- Converted the date into a date, time format and categorized the indicator into synthetic opioids, natural and semisynthetic, opioids, heroine cocaine, etc., and grouped the total that's as total Overdose deaths.
- Categories the Geo spatial state data into categories of Northeast Midwest south and west.
- Categorized the months and divided them into seasonal data, such as winter spring summer and fall.

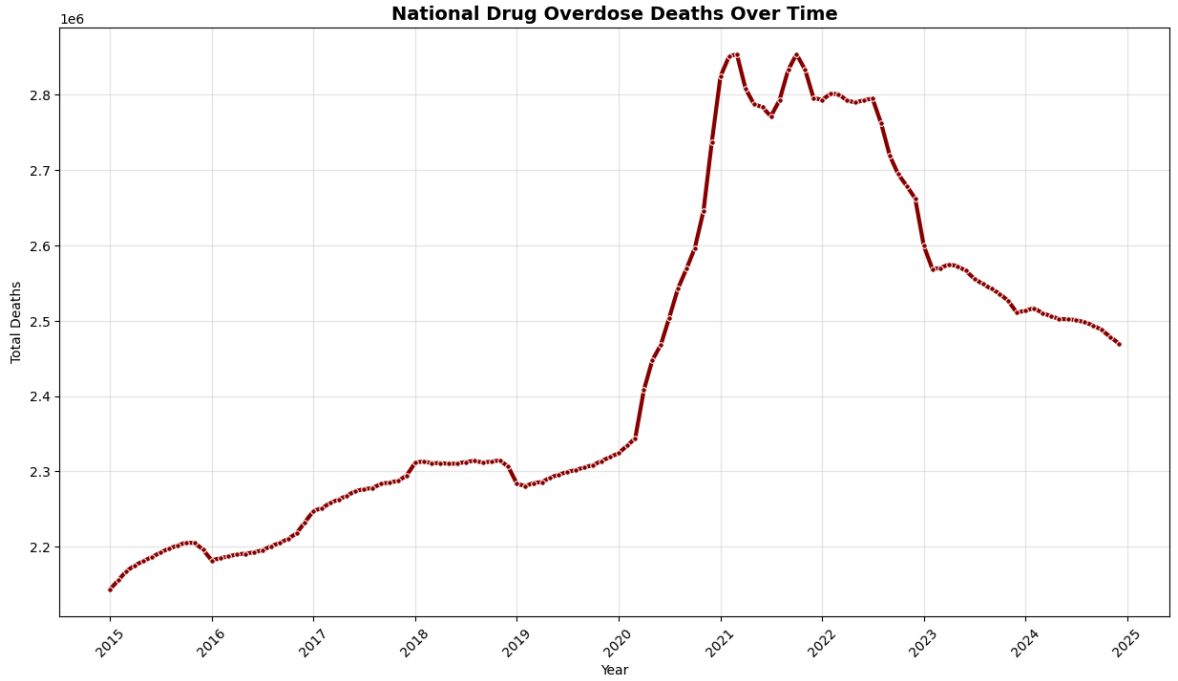
## 3) Data Exploration:

### Time series:

In [ ]:
```
total_deaths = df_main[df_main['Drug_Category'] == 'Total Deaths'].copy()
total_deaths = total_deaths.dropna(subset=['Data Value'])
```

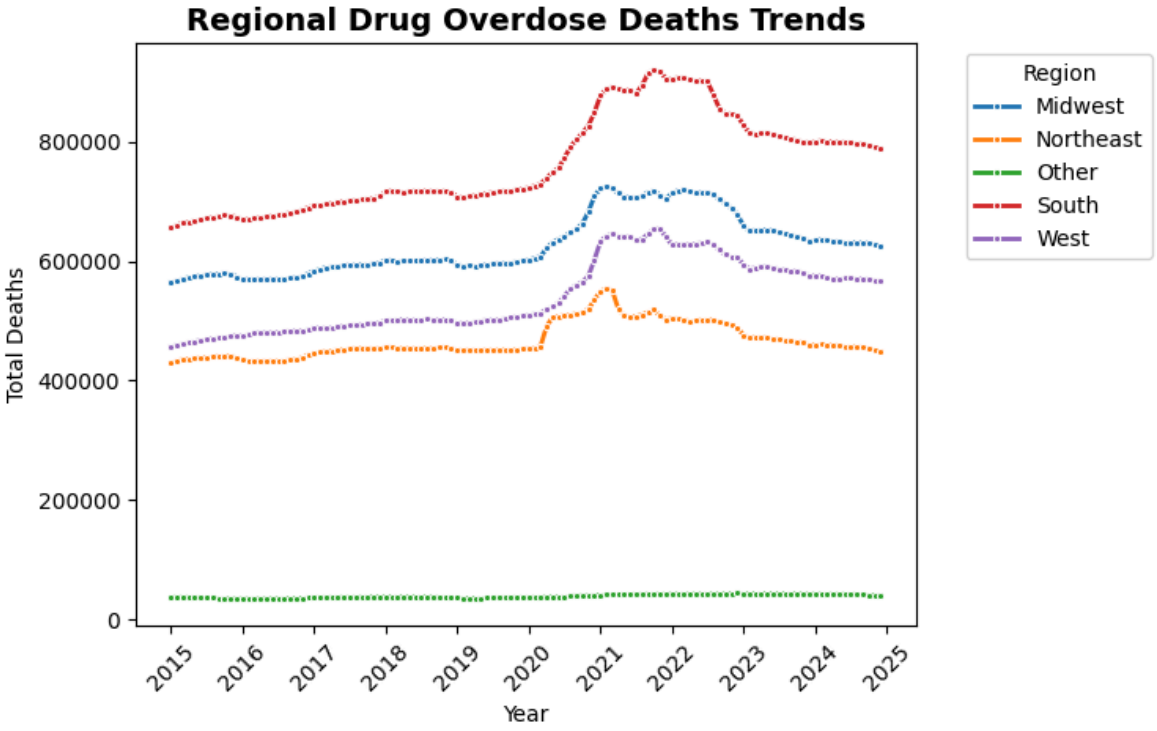
In [ ]:
```
# Regional trends
plt.figure(figsize=(15, 8))
national_trends = total_deaths.groupby(['Date'])['Data Value'].sum().reset_index


sns.lineplot(data=national_trends, x='Date', y='Data Value',
             linewidth=3, color='darkred', marker='o', markersize=4)
plt.title('National Drug Overdose Deaths Over Time', fontsize=14, fontweight='bo
```

```
plt.xlabel('Year')
plt.ylabel('Total Deaths')
plt.xticks(rotation=45)
plt.grid(True, alpha=0.3)
```




In [ ]:
```
# Regional trends

regional_trends = total_deaths.groupby(['Date', 'Region'])['Data Value'].sum().r


sns.lineplot(data=regional_trends, x='Date', y='Data Value',
             hue='Region', linewidth=2, marker='o', markersize=3)
plt.title('Regional Drug Overdose Deaths Trends', fontsize=14, fontweight='bold'
plt.xlabel('Year')
plt.ylabel('Total Deaths')
plt.xticks(rotation=45)
plt.legend(title='Region', bbox_to_anchor=(1.05, 1), loc='upper left')
```

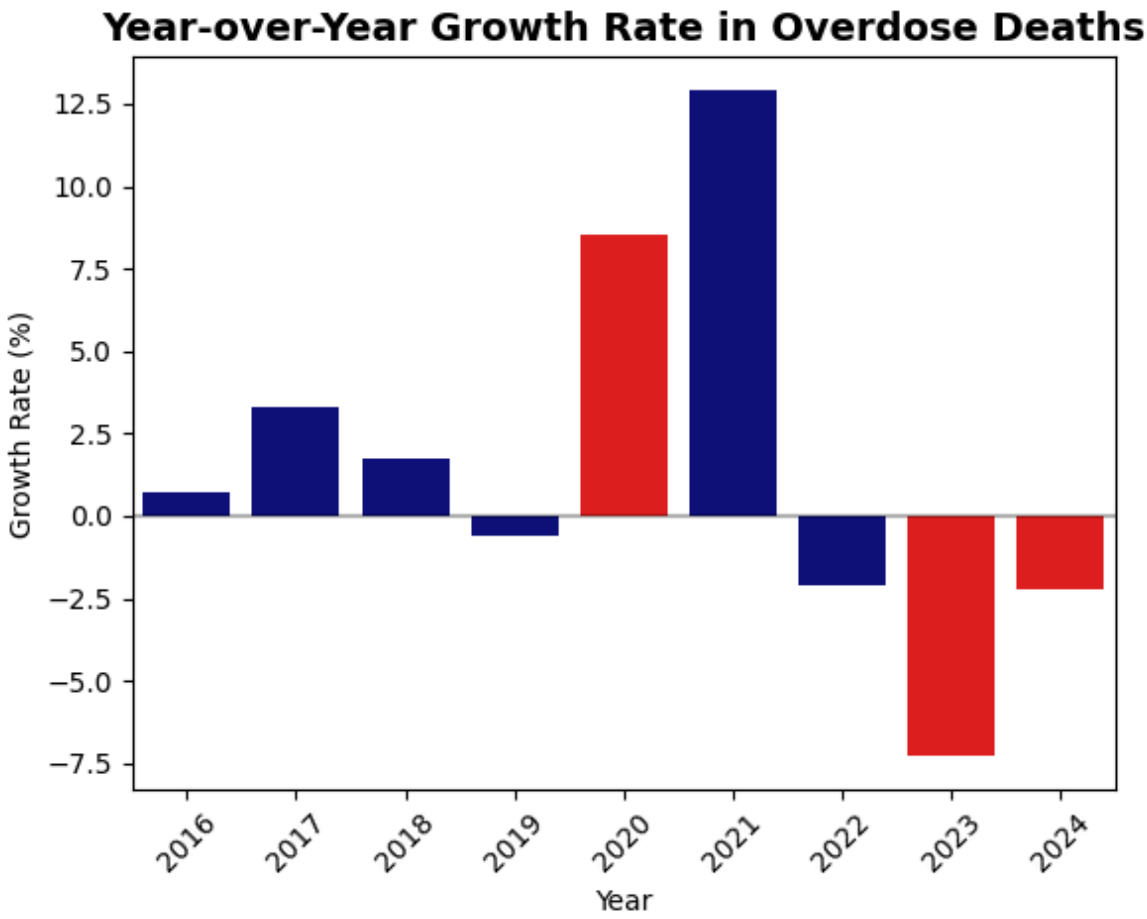
Out[ ]:
```
<matplotlib.legend.Legend at 0x7b7814835cd0>
```




In [ ]:
```
# Year-over-year analysis

yearly_totals = total_deaths.groupby(['Year'])['Data Value'].sum().reset_index()
yearly_totals['Growth_Rate'] = yearly_totals['Data Value'].pct_change() * 100


colors = ['red' if x < 0 else 'darkblue' for x in yearly_totals['Growth_Rate'].f
sns.barplot(data=yearly_totals[1:], x='Year', y='Growth_Rate', palette=colors)
plt.title('Year-over-Year Growth Rate in Overdose Deaths', fontsize=14, fontweig
plt.xlabel('Year')
plt.ylabel('Growth Rate (%)')
plt.axhline(y=0, color='black', linestyle='-', alpha=0.3)
plt.xticks(rotation=45)
```

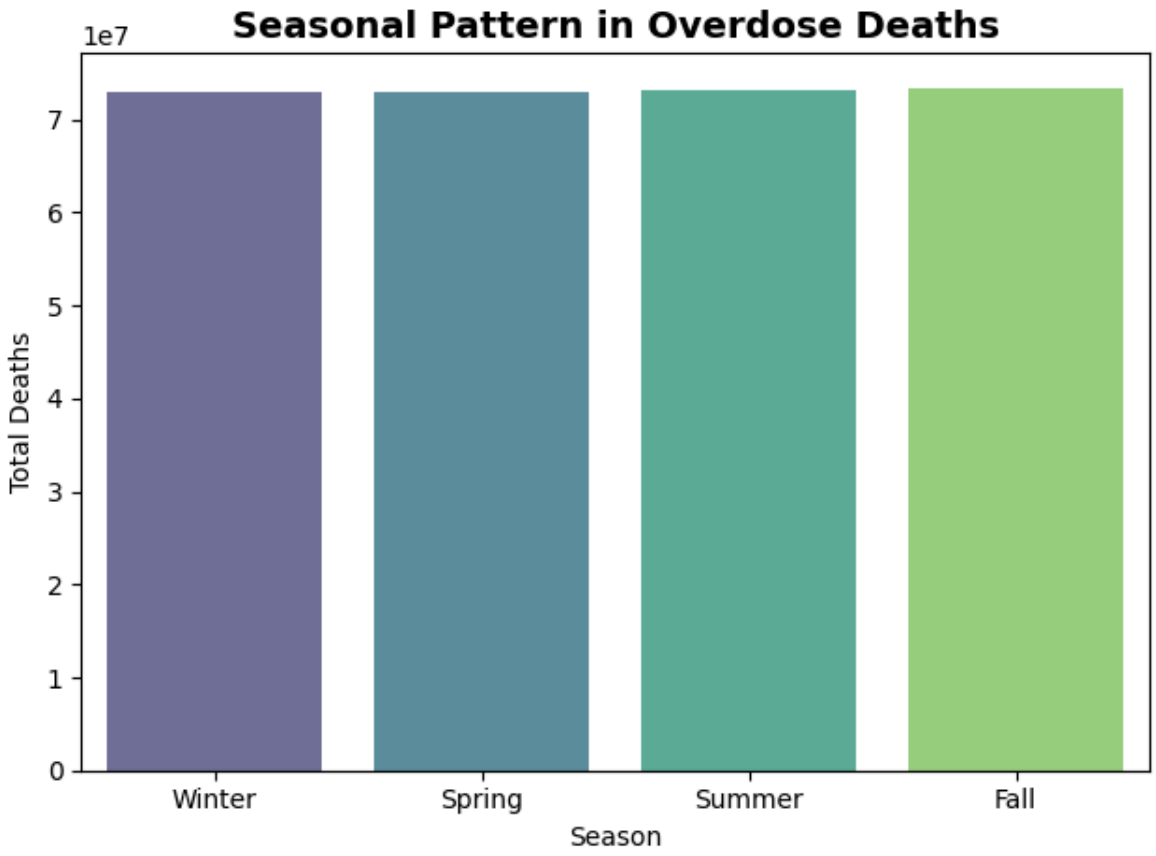
```
<ipython-input-19-3353575355>:8: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v
0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effe
ct.

  sns.barplot(data=yearly_totals[1:], x='Year', y='Growth_Rate', palette=colors)
<ipython-input-19-3353575355>:8: UserWarning: The palette list has more values (1
0) than needed (9), which may not be intended.
  sns.barplot(data=yearly_totals[1:], x='Year', y='Growth_Rate', palette=colors)
```

Out[ ]:
```
([0, 1, 2, 3, 4, 5, 6, 7, 8],
 [Text(0, 0, '2016'),
  Text(1, 0, '2017'),
  Text(2, 0, '2018'),
  Text(3, 0, '2019'),
  Text(4, 0, '2020'),
  Text(5, 0, '2021'),
  Text(6, 0, '2022'),
  Text(7, 0, '2023'),
  Text(8, 0, '2024')])
```




In [ ]:
```
#Seasonal patterns
seasonal_data = total_deaths.groupby(['Season'])['Data Value'].sum().reset_index


season_order = ['Winter', 'Spring', 'Summer', 'Fall']
seasonal_data['Season'] = pd.Categorical(seasonal_data['Season'], categories=sea
seasonal_data = seasonal_data.sort_values('Season')

sns.barplot(data=seasonal_data, x='Season', y='Data Value',
           palette='viridis', alpha=0.8)
plt.title('Seasonal Pattern in Overdose Deaths', fontsize=14, fontweight='bold')
plt.xlabel('Season')
plt.ylabel('Total Deaths')

plt.tight_layout()
plt.savefig('temporal_trends_analysis.png', dpi=300, bbox_inches='tight')
plt.show()
```

```
<ipython-input-20-3758656200>:9: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v
0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effe
ct.

  sns.barplot(data=seasonal_data, x='Season', y='Data Value',
```




## Insights:

- The other region shows higher deaths when compared to all the other regions in America.
- The year over your growth rate shows there is a significant drop in deaths in the year 2023 and 2024.
- The seasonal pattern for overdose deaths doesn't show any significant pattern in the total number of deaths as as all the seasons show equal deaths.

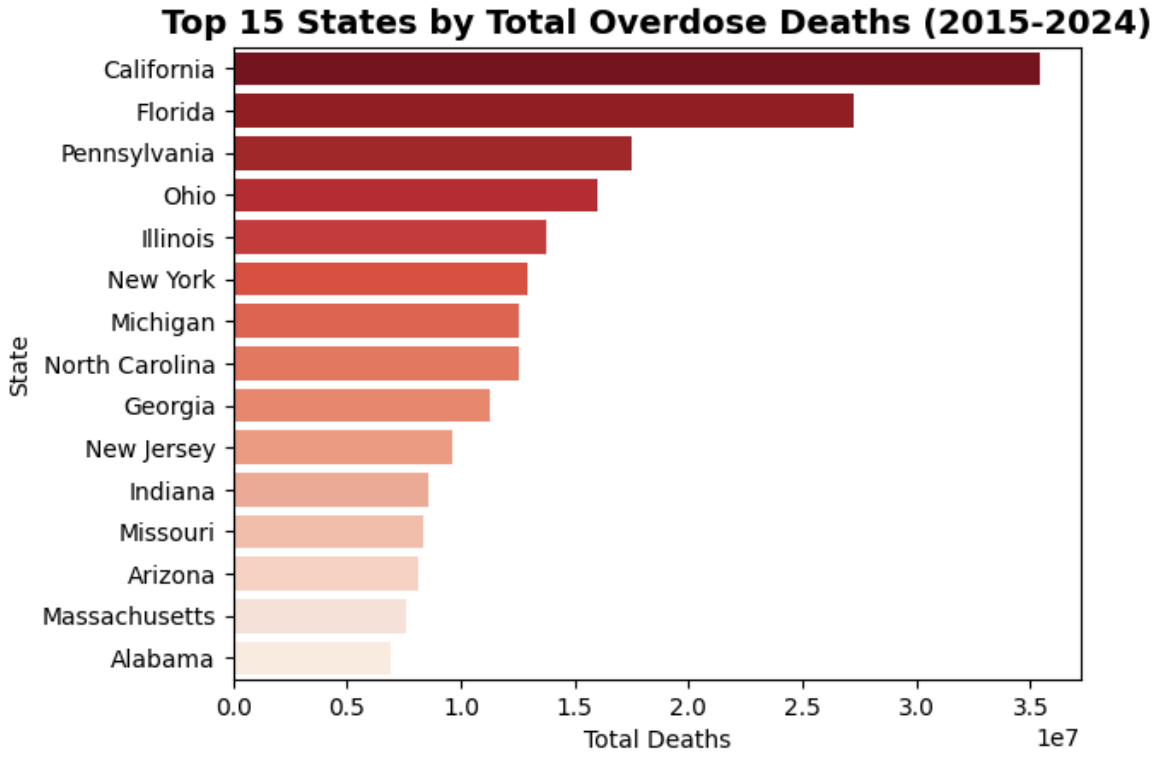
## Geographic Analysis:

In [ ]:
```
state_totals = total_deaths.groupby(['State Name'])['Data Value'].sum().reset_in
state_totals = state_totals.sort_values('Data Value', ascending=False)
```

In [ ]:
```
# Top 15 states by total deaths

top_15_states = state_totals.head(15)
sns.barplot(data=top_15_states, y='State Name', x='Data Value',
            palette='Reds_r', orient='h')
plt.title('Top 15 States by Total Overdose Deaths (2015-2024)', fontsize=14, fon
plt.xlabel('Total Deaths')
plt.ylabel('State')
```

```
<ipython-input-22-3906940494>:4: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v
0.14.0. Assign the `y` variable to `hue` and set `legend=False` for the same effe
ct.

  sns.barplot(data=top_15_states, y='State Name', x='Data Value',
```

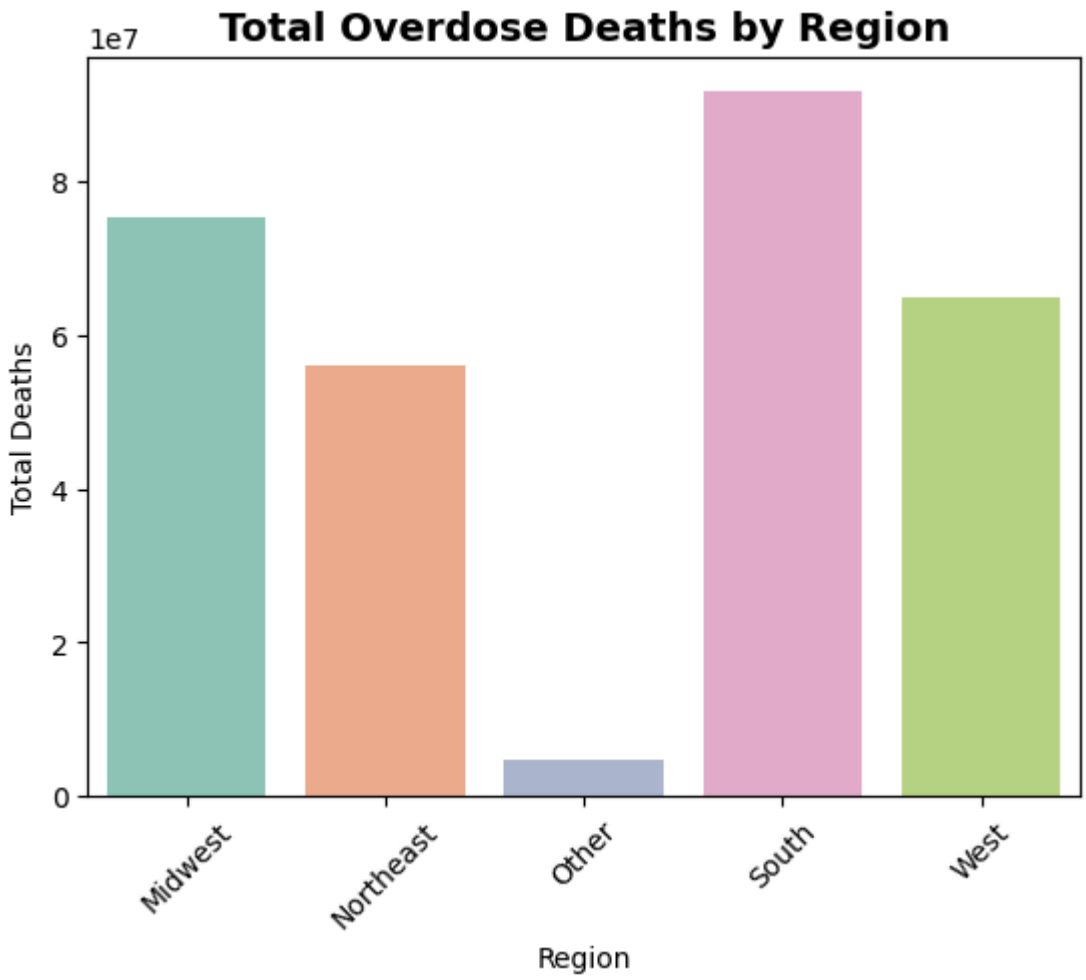
Out[ ]:
```
Text(0, 0.5, 'State')
```



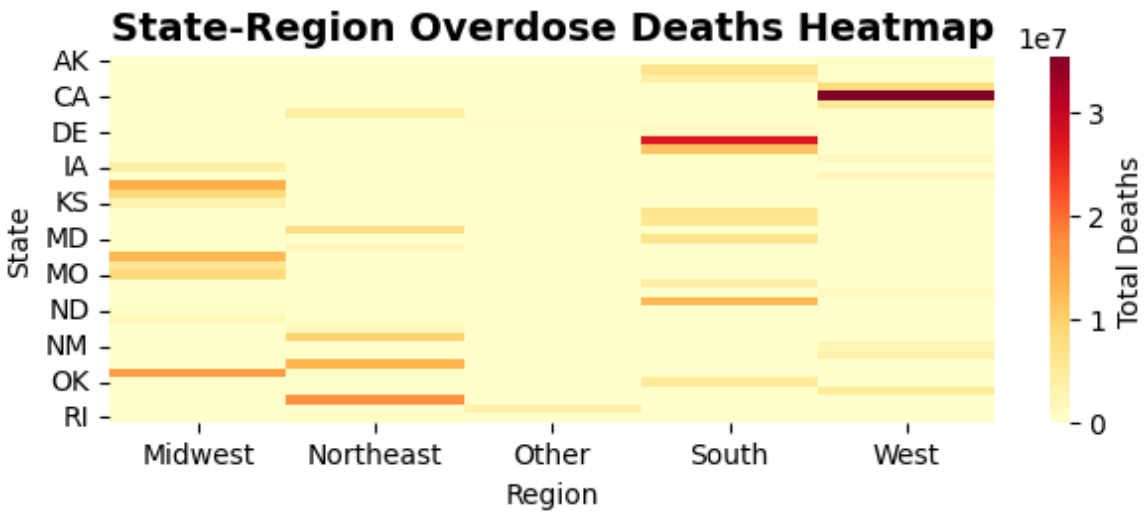

In [ ]:
```
# Regional comparison
regional_totals = total_deaths.groupby(['Region'])['Data Value'].sum().reset_ind


sns.barplot(data=regional_totals, x='Region', y='Data Value',
            palette='Set2', alpha=0.8)
plt.title('Total Overdose Deaths by Region', fontsize=14, fontweight='bold')
plt.xlabel('Region')
plt.ylabel('Total Deaths')
plt.xticks(rotation=45)
```

```
<ipython-input-23-3423443340>:5: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v
0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effe
ct.

  sns.barplot(data=regional_totals, x='Region', y='Data Value',
```

Out[ ]:
```
([0, 1, 2, 3, 4],
 [Text(0, 0, 'Midwest'),
  Text(1, 0, 'Northeast'),
  Text(2, 0, 'Other'),
  Text(3, 0, 'South'),
  Text(4, 0, 'West')])
```




In [ ]:
```
# State vs Region heatmap

state_region_data = total_deaths.groupby(['State', 'Region'])['Data Value'].sum(
pivot_data = state_region_data.pivot_table(values='Data Value', index='State', c

ax3 = plt.subplot(2, 1, 2)
sns.heatmap(pivot_data, annot=False, cmap='YlOrRd', cbar_kws={'label': 'Total De
plt.title('State-Region Overdose Deaths Heatmap', fontsize=14, fontweight='bold'
plt.xlabel('Region')
plt.ylabel('State')

plt.tight_layout()
plt.savefig('geographic_analysis.png', dpi=300, bbox_inches='tight')
plt.show()
```




## Insights:

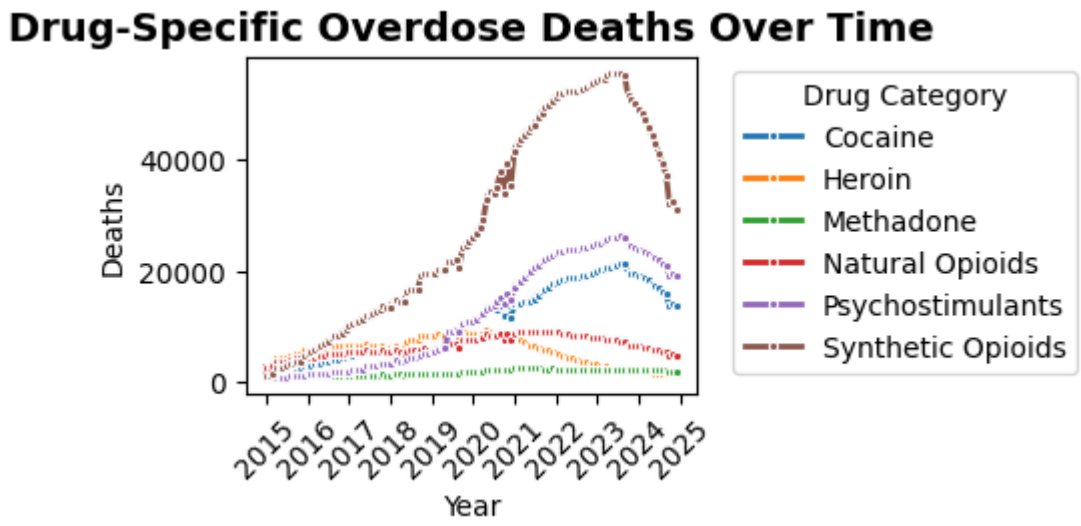
- California has the highest deaths during the time of 2015 to 2024 due to overdose, followed by Florida and Texas.
- South region has more deaths compared to all the rest of the regions while the northeast has the least deaths due to overdose.
- The size of the state has an impact on the number of deaths with larger states having higher number of deaths and smaller states having lower number of deaths.

## 3.3 Drug-Specific Analysis

In [ ]:
```
drug_specific = df_main[~df_main['Drug_Category'].isin(['Total Deaths', 'All Opi
drug_specific = drug_specific.dropna(subset=['Data Value'])
```

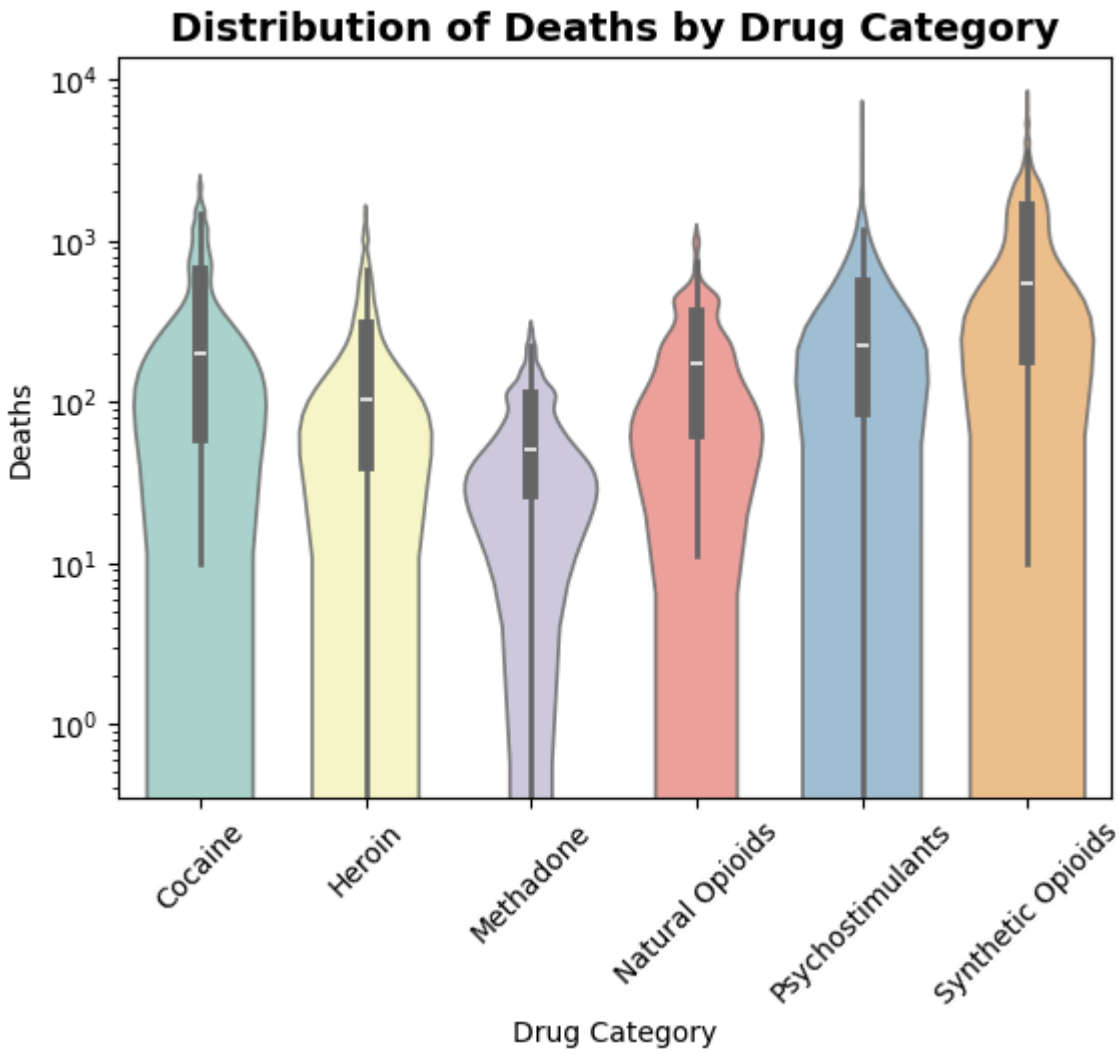
In [ ]:
```
drug_trends = drug_specific.groupby(['Date', 'Drug_Category'])['Data Value'].sum

ax1 = plt.subplot(2, 2, 1)
sns.lineplot(data=drug_trends, x='Date', y='Data Value',
             hue='Drug_Category', linewidth=2, marker='o', markersize=3)
plt.title('Drug-Specific Overdose Deaths Over Time', fontsize=14, fontweight='bo
plt.xlabel('Year')
plt.ylabel('Deaths')
plt.xticks(rotation=45)
plt.legend(title='Drug Category', bbox_to_anchor=(1.05, 1), loc='upper left')
```

Out[ ]:
```
<matplotlib.legend.Legend at 0x7b781493f3d0>
```



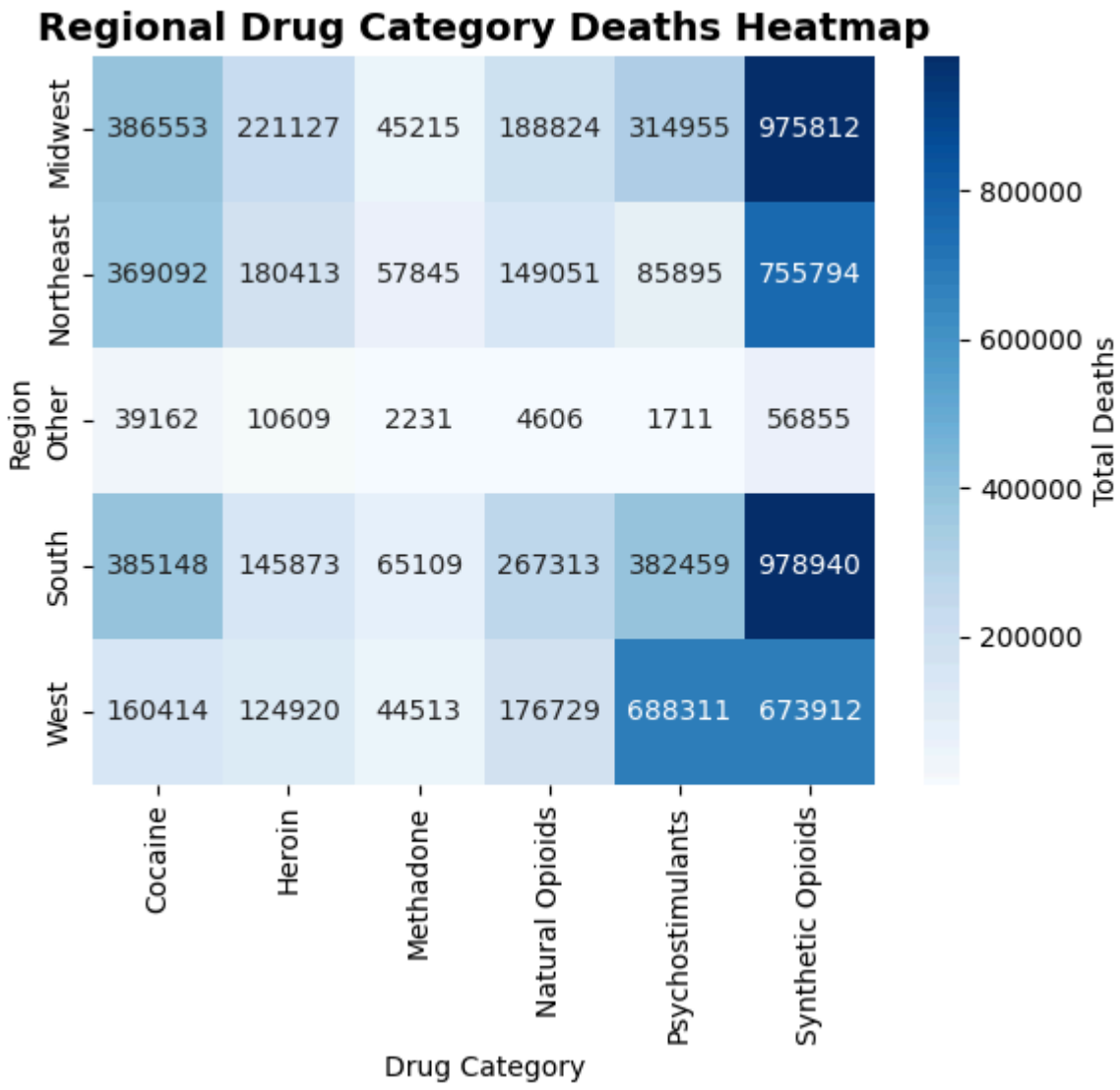

In [ ]:
```
drug_totals = drug_specific.groupby('Drug_Category')['Data Value'].sum().reset_i


sns.violinplot(data=drug_specific, x='Drug_Category', y='Data Value',
               palette='Set3', alpha=0.8)
plt.title('Distribution of Deaths by Drug Category', fontsize=14, fontweight='bo
plt.xlabel('Drug Category')
plt.ylabel('Deaths')
plt.xticks(rotation=45)
plt.yscale('log')
```

```
<ipython-input-27-3058451950>:4: FutureWarning:

Passing `palette` without assigning `hue` is deprecated and will be removed in v
0.14.0. Assign the `x` variable to `hue` and set `legend=False` for the same effe
ct.

  sns.violinplot(data=drug_specific, x='Drug_Category', y='Data Value',
```

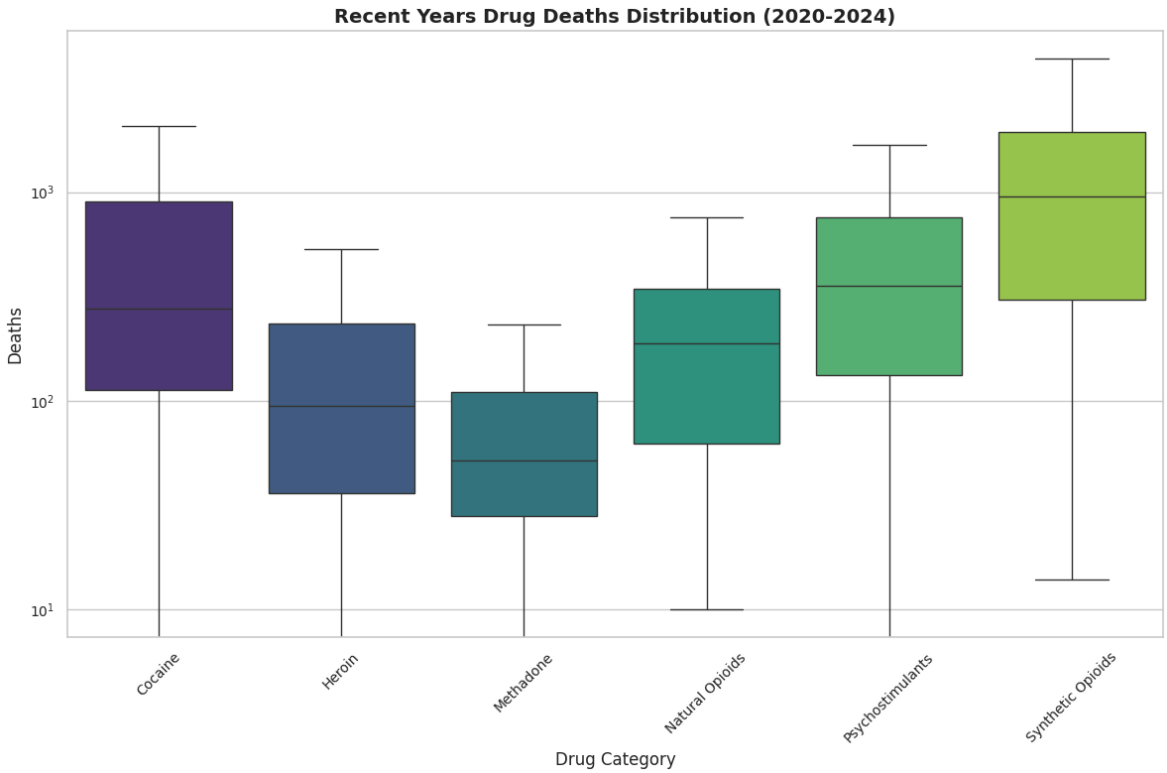



In [ ]:
```
regional_drug = drug_specific.groupby(['Region', 'Drug_Category'])['Data Value']


pivot_regional_drug = regional_drug.pivot(index='Region', columns='Drug_Category
pivot_regional_drug = pivot_regional_drug.fillna(0)

sns.heatmap(pivot_regional_drug, annot=True, fmt='.0f', cmap='Blues',
            cbar_kws={'label': 'Total Deaths'})
plt.title('Regional Drug Category Deaths Heatmap', fontsize=14, fontweight='bold
plt.xlabel('Drug Category')
plt.ylabel('Region')
```

Out[ ]:
```
Text(50.722222222222214, 0.5, 'Region')
```




In [ ]:
```
recent_years = drug_specific[drug_specific['Year'] >= 2020]


sns.boxplot(data=recent_years, x='Drug_Category', y='Data Value',
            palette='viridis', showfliers=False)
plt.title('Recent Years Drug Deaths Distribution (2020-2024)', fontsize=14, font
plt.xlabel('Drug Category')
plt.ylabel('Deaths')
plt.xticks(rotation=45)
plt.yscale('log')

plt.tight_layout()
plt.savefig('drug_specific_analysis.png', dpi=300, bbox_inches='tight')
plt.show()
```

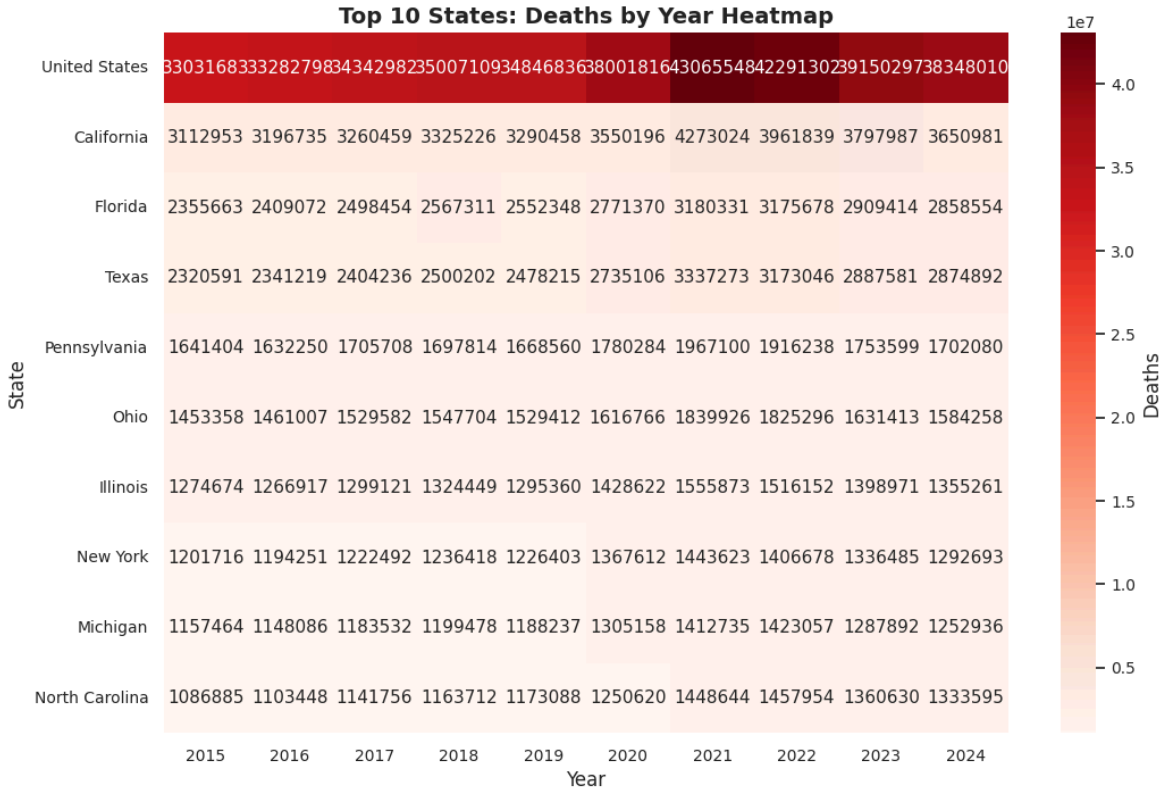



In [ ]:
```
correlation_data = total_deaths.pivot_table(values='Data Value',
                                            index=['State', 'Year'],
                                            columns='Month',
                                            fill_value=0)
```

In [ ]:
```
# State performance over time
state_trends = total_deaths.groupby(['State Name', 'Year'])['Data Value'].sum().
pivot_state_year = state_trends.pivot(index='State Name', columns='Year', values
pivot_state_year = pivot_state_year.fillna(0)
```

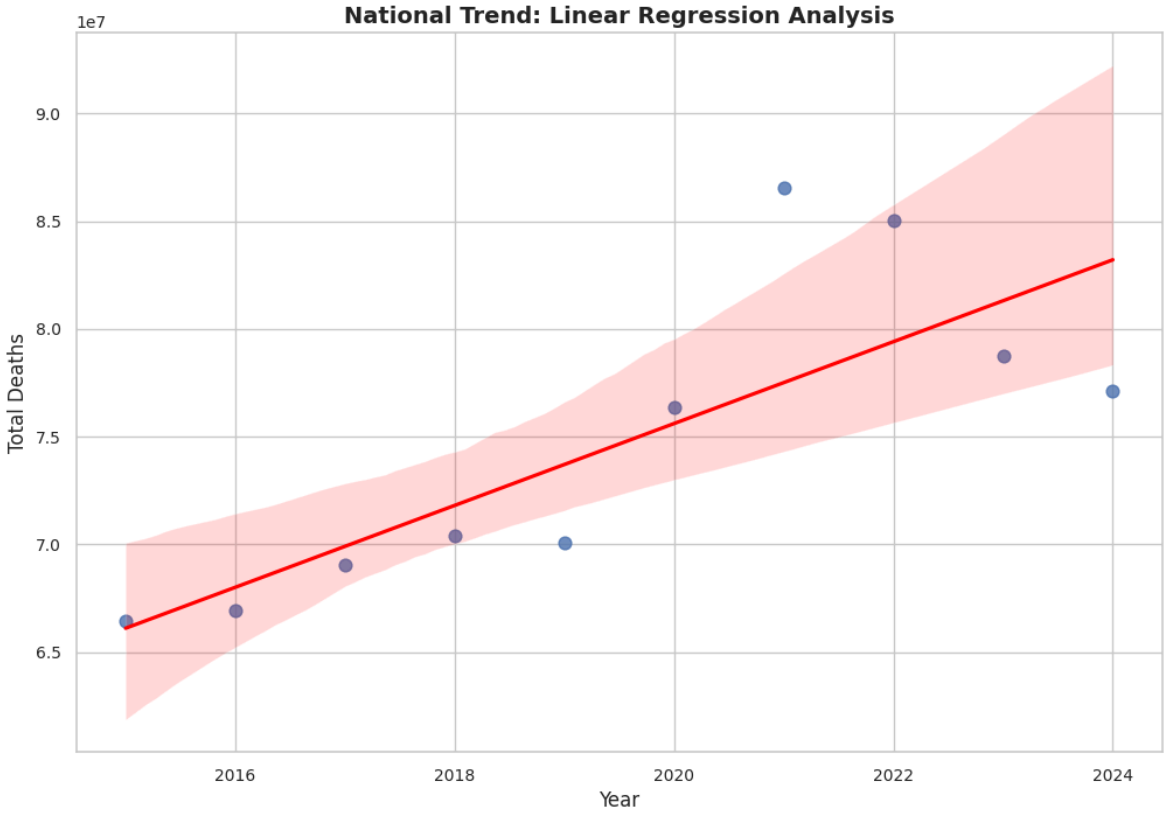
In [ ]:
```
# Select top 10 states for readability
top_states = state_totals.head(10)['State Name'].tolist()
pivot_top_states = pivot_state_year.loc[top_states]

sns.heatmap(pivot_top_states, annot=True, fmt='.0f', cmap='Reds',
            cbar_kws={'label': 'Deaths'})
plt.title('Top 10 States: Deaths by Year Heatmap', fontsize=14, fontweight='bold
plt.xlabel('Year')
plt.ylabel('State')
```

Out[ ]:
```
Text(117.24999999999999, 0.5, 'State')
```




In [ ]:
```
# Regression analysis - year vs deaths

yearly_national = total_deaths.groupby('Year')['Data Value'].sum().reset_index()
sns.regplot(data=yearly_national, x='Year', y='Data Value',
            scatter_kws={'s': 60}, line_kws={'color': 'red'})
plt.title('National Trend: Linear Regression Analysis', fontsize=14, fontweight=
plt.xlabel('Year')
plt.ylabel('Total Deaths')
```

Out[ ]:
```
Text(0, 0.5, 'Total Deaths')
```



In [ ]:
```
# Distribution analysis
# Filter for reasonable scale
filtered_data = total_deaths[total_deaths['Data Value'] < 10000]
sns.histplot(data=filtered_data, x='Data Value', kde=True,
             bins=50, alpha=0.7, color='skyblue')
plt.title('Distribution of Death Counts (Filtered)', fontsize=14, fontweight='bo
plt.xlabel('Deaths')
plt.ylabel('Frequency')

plt.tight_layout()
plt.savefig('statistical_analysis.png', dpi=300, bbox_inches='tight')
plt.show
```

Out[ ]:

**matplotlib.pyplot.show**

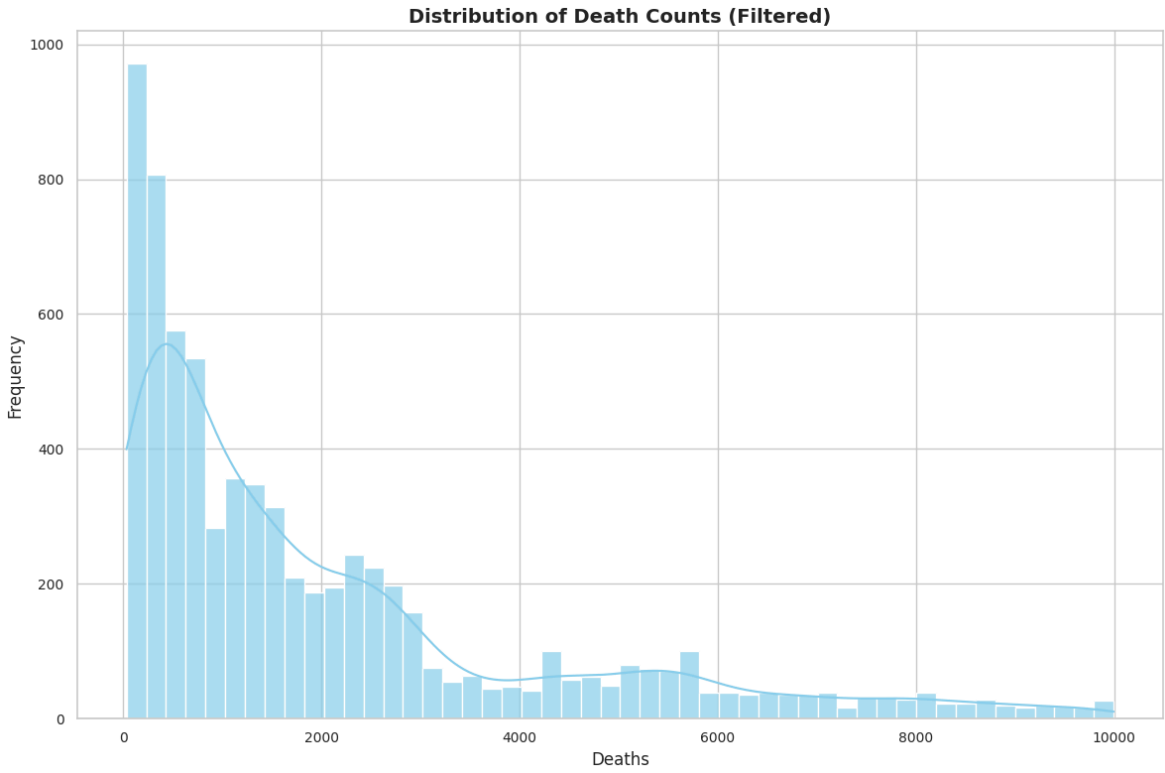
def show(*args, **kwargs) -> None

Display all open figures.

Parameters

---

block : bool, optional

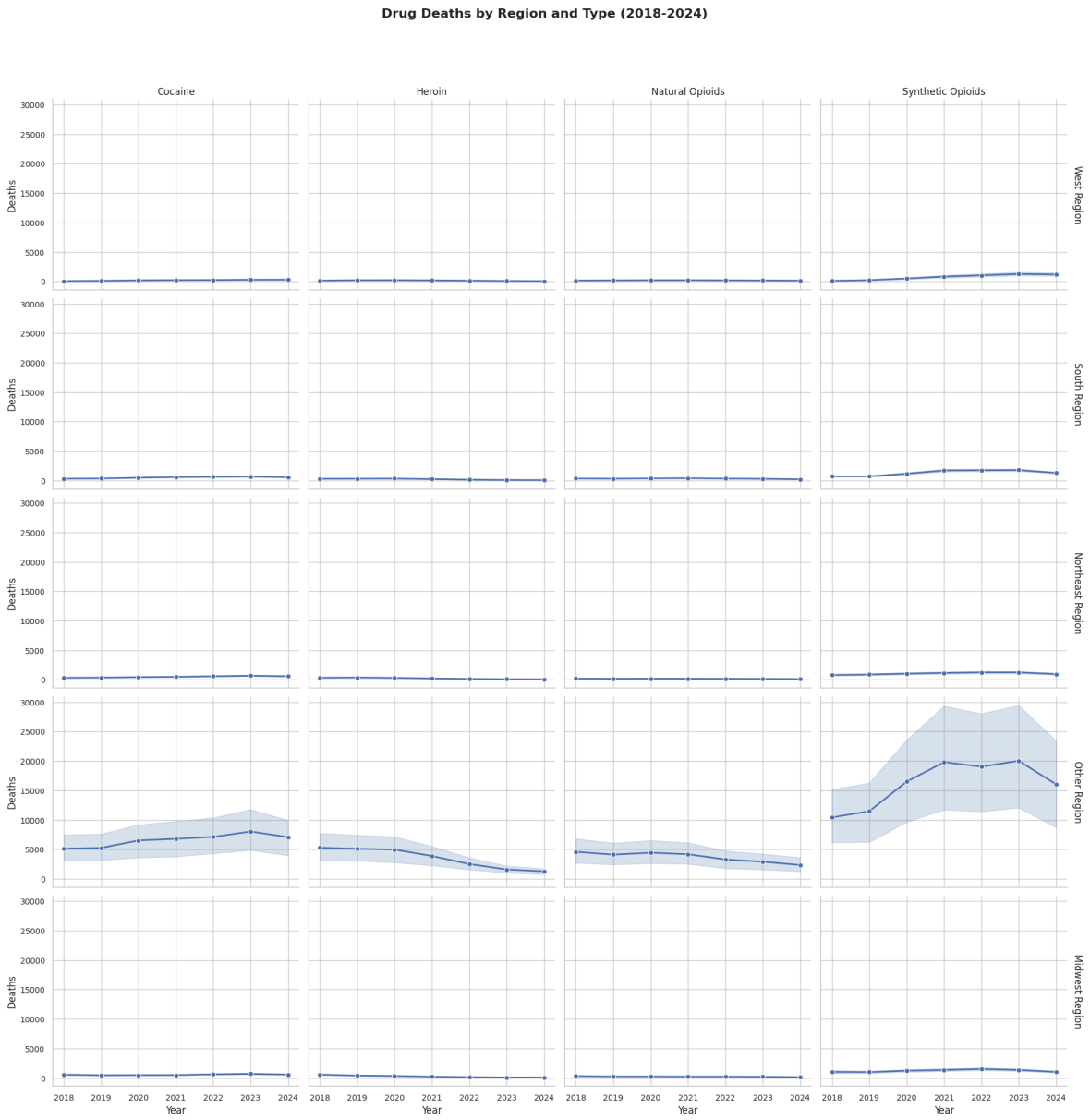



# Advance Visualisation:

In [97]:
```
facet_data = drug_specific[drug_specific['Drug_Category'].isin(['Synthetic Opioi
facet_data = facet_data[facet_data['Year'] >= 2018]
```

In [98]:
```
g = sns.FacetGrid(facet_data, col='Drug_Category', row='Region',
                  height=4, aspect=1.2, margin_titles=True)
g.map(sns.lineplot, 'Year', 'Data Value', marker='o', linewidth=2)
g.set_axis_labels('Year', 'Deaths')
g.set_titles(col_template='{col_name}', row_template='{row_name} Region')
```

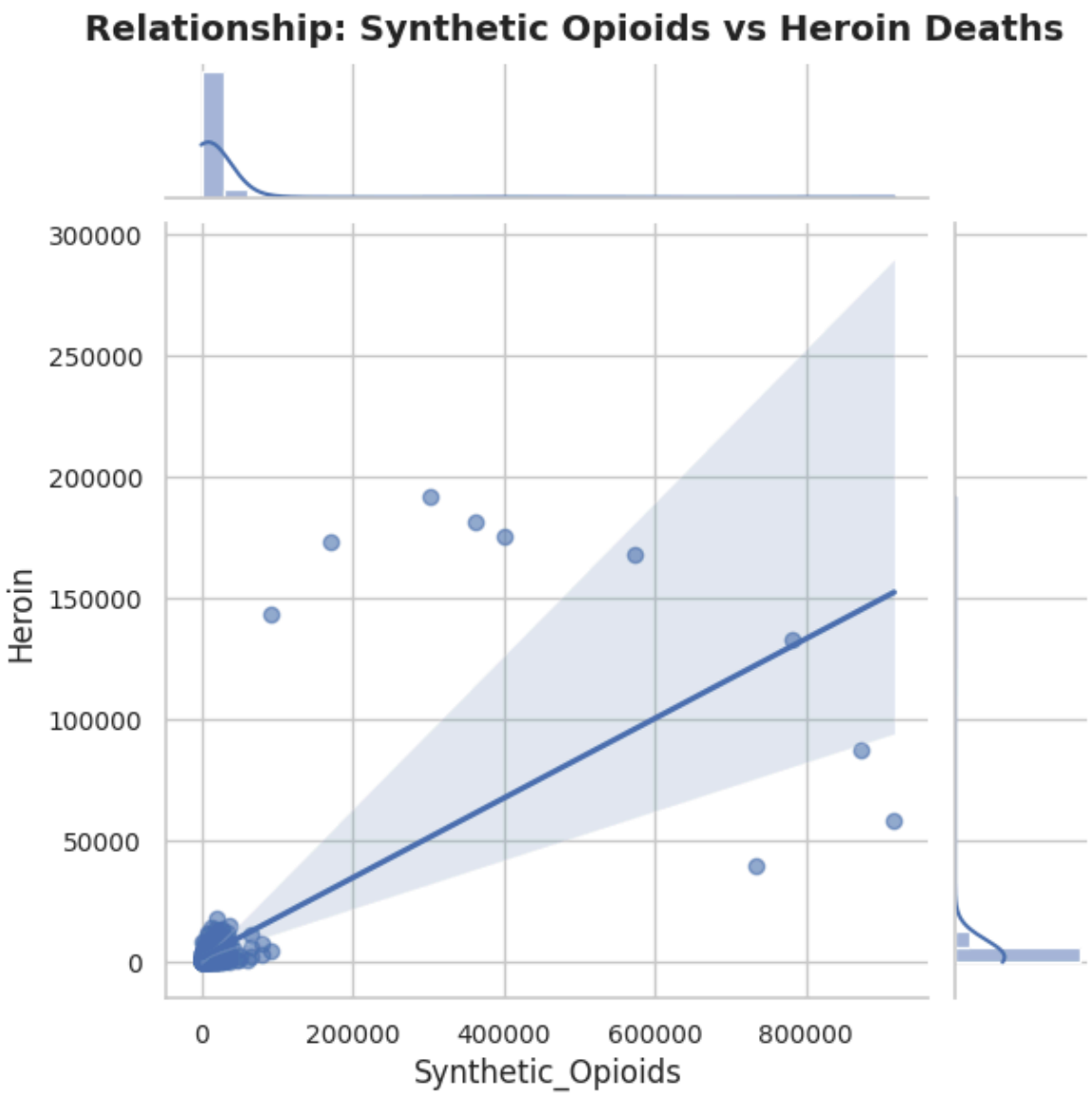
```
plt.subplots_adjust(top=0.9)
g.fig.suptitle('Drug Deaths by Region and Type (2018-2024)', fontsize=16, fontwe
plt.savefig('facetgrid_analysis.png', dpi=300, bbox_inches='tight')
plt.show()
```




In [99]:
```
synthetic_opioids = drug_specific[drug_specific['Drug_Category'] == 'Synthetic O
heroin = drug_specific[drug_specific['Drug_Category'] == 'Heroin']
```

In [100…
```
merged_drugs = pd.merge(
    synthetic_opioids.groupby(['State', 'Year'])['Data Value'].sum().reset_index
    heroin.groupby(['State', 'Year'])['Data Value'].sum().reset_index().rename(c
    on=['State', 'Year'], how='inner'
)

plt.figure(figsize=(12, 8))
g = sns.jointplot(data=merged_drugs, x='Synthetic_Opioids', y='Heroin',
                  kind='reg', scatter_kws={'alpha': 0.6},
                  marginal_kws={'bins': 30})
g.fig.suptitle('Relationship: Synthetic Opioids vs Heroin Deaths',
               fontsize=14, fontweight='bold', y=1.02)
plt.savefig('jointplot_analysis.png', dpi=300, bbox_inches='tight')
plt.show()
```

```
<Figure size 1200x800 with 0 Axes>
```



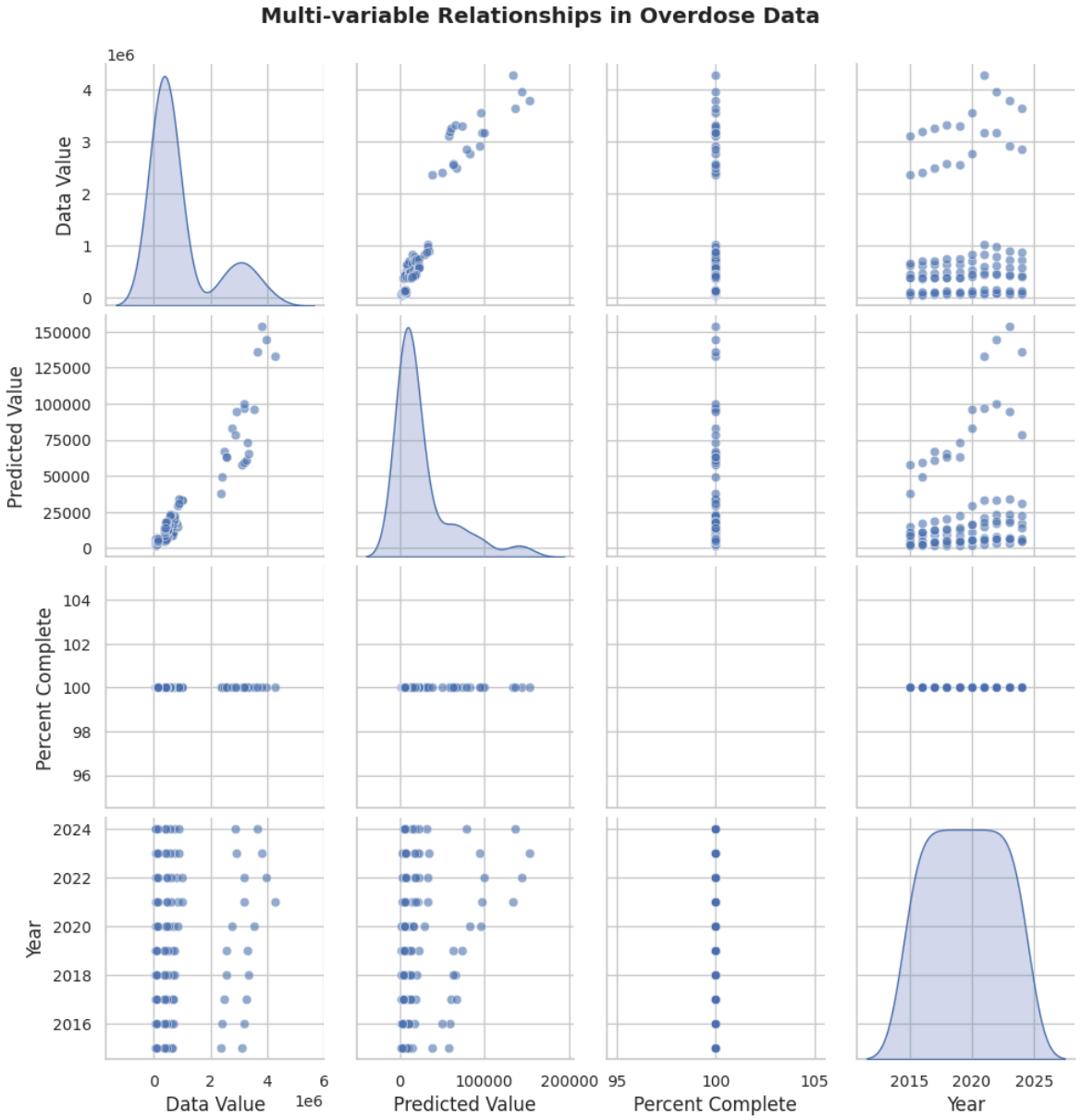

In [101…
```
state_drug_matrix = drug_specific.groupby(['State Name', 'Drug_Category'])['Data
```

In [103…
```
state_totals_matrix = state_drug_matrix.sum(axis=1)
top_states_for_clustering = state_totals_matrix.nlargest(20).index
clustering_data = state_drug_matrix.loc[top_states_for_clustering]

plt.figure(figsize=(14, 10))
g = sns.clustermap(clustering_data, cmap='YlOrRd',
                   standard_scale=1, figsize=(14, 10),
                   dendrogram_ratio=0.15, cbar_pos=(0.02, 0.8, 0.03, 0.15))
g.ax_heatmap.set_title('State Clustering by Drug Death Patterns',
                       fontsize=14, fontweight='bold', pad=20)
plt.savefig('clustermap_analysis.png', dpi=300, bbox_inches='tight')
plt.show()
```

```
<Figure size 1400x1000 with 0 Axes>
```


In [104…

```
pairplot_data = []
for state in total_deaths['State Name'].unique()[:10]:  # Top 10 states
    state_data = total_deaths[total_deaths['State Name'] == state]
    yearly_summary = state_data.groupby('Year').agg({
        'Data Value': 'sum',
        'Predicted Value': 'sum',
        'Percent Complete': 'mean'
    }).reset_index()
    yearly_summary['State'] = state
    pairplot_data.append(yearly_summary)

pairplot_df = pd.concat(pairplot_data, ignore_index=True)
pairplot_df = pairplot_df.dropna()

g = sns.pairplot(pairplot_df[['Data Value', 'Predicted Value', 'Percent Complete
                 diag_kind='kde', plot_kws={'alpha': 0.6})
g.fig.suptitle('Multi-variable Relationships in Overdose Data',
               fontsize=14, fontweight='bold', y=1.02)
plt.savefig('pairplot_analysis.png', dpi=300, bbox_inches='tight')
plt.show()
```




# Statistics

In [ ]:
```
yearly_national = total_deaths.groupby('Year')['Data Value'].sum().reset_index()
correlation_coef, p_value = pearsonr(yearly_national['Year'], yearly_national['D
```

In [ ]:
```
deaths_2023 = yearly_national[yearly_national['Year'] == 2023]['Data Value'].ilo
deaths_2024 = yearly_national[yearly_national['Year'] == 2024]['Data Value'].ilo
percent_change = ((deaths_2024 - deaths_2023) / deaths_2023) * 100

print(f"\n2024 vs 2023 Analysis:")
print(f"2023 Deaths: {deaths_2023:,.0f}")
print(f"2024 Deaths: {deaths_2024:,.0f}")
print(f"Percent Change: {percent_change:.1f}%")
```

```
2024 vs 2023 Analysis:
2023 Deaths: 30,667,436
2024 Deaths: 29,976,674
Percent Change: -2.3%
```

In [ ]:
```
regional_stats = total_deaths.groupby('Region')['Data Value'].agg(['sum', 'mean'
print("Regional Statistics:")
```

```
print(regional_stats)
```

```
Regional Statistics:
                  sum      mean       std  count
Region
Midwest    75322230.0  31384.26  41232.08   2400
Northeast  56070416.0  31822.03  43377.98   1762
Other       4641754.0   9670.32  12940.73    480
South      91668169.0  34722.79  51100.58   2640
West       64895245.0  27039.69  62590.87   2400
```

In [ ]:
```
drug_stats = drug_specific.groupby('Drug_Category')['Data Value'].agg(['sum', 'm
print("Drug Category Statistics:")
print(drug_stats)
```

```
Drug Category Statistics:
                         sum     mean      std  count
Drug_Category
Cocaine            1340369.0   409.90   483.97   3270
Heroin              682942.0   223.40   284.31   3057
Methadone           214913.0    71.30    58.24   3014
Natural Opioids     786523.0   231.60   217.05   3396
Psychostimulants   1473331.0   461.14   840.09   3195
Synthetic Opioids  3441313.0  1050.78  1247.27   3275
```

In [ ]:
```
seasonal_stats = total_deaths.groupby('Season')['Data Value'].agg(['sum', 'mean'
print("Seasonal Statistics:")
print(seasonal_stats)
```

```
Seasonal Statistics:
                sum      mean       std
Season
Fall    73451336.0  30351.79  50028.35
Spring  72938473.0  30127.42  49725.21
Summer  73206394.0  30238.08  49860.41
Winter  73001611.0  30165.95  49785.40
```

# Key Findings

In [ ]:
```
print(f"1. OVERALL SCALE:")
print(f" • Total deaths (2015-2024): {total_deaths['Data Value'].sum():,.0f}")
print(f" • Peak year: {yearly_national.loc[yearly_national['Data Value'].idxmax(
print(f" • Recent improvement: {percent_change:.1f}% change in 2024")
```

1. OVERALL SCALE:
   - Total deaths (2015-2024): 292,597,814
   - Peak year: 2021
   - Recent improvement: -2.3% change in 2024

In [ ]:
```
top_state = state_totals.iloc[1]
print(f"\n2. GEOGRAPHIC PATTERNS:")
print(f"    • Highest burden state: {top_state['State Name']} ({top_state['Data V
print(f"    • Most affected region: {regional_totals.loc[regional_totals['Data Va
print(f"    • States with data: {df['State'].nunique()}")
```

2. GEOGRAPHIC PATTERNS:
   - Highest burden state: Florida (27,278,195 deaths)
   - Most affected region: South
   - States with data: 41

In [ ]:
```
top_drug = drug_stats.loc[drug_stats['sum'].idxmax()]
print(f"\n3. DRUG-SPECIFIC PATTERNS:")
print(f" • Most deadly category: {top_drug.name}")
print(f" • Total deaths from {top_drug.name}: {top_drug['sum']:,.0f}")
print(f" • Drug categories tracked: {len(drug_stats)}")
```

3. DRUG-SPECIFIC PATTERNS:
- Most deadly category: Synthetic Opioids
- Total deaths from Synthetic Opioids: 3,441,313
- Drug categories tracked: 6

In [ ]:
```
print(f"\n4. TEMPORAL PATTERNS:")
print(f" • Years of data: {df['Year'].nunique()} years")
print(f" • Months analyzed: {df.shape[0]:,} data points")
print(f" • Trend correlation: {correlation_coef:.3f} ({'Strong' if abs(correlati
```

4. TEMPORAL PATTERNS:
- Years of data: 10 years
- Months analyzed: 56,243 data points
- Trend correlation: 0.776 (Strong)

In [ ]:
```
print(f"\n5. DATA QUALITY:")
print(f" • Records with data: {df_main.dropna(subset=['Data Value']).shape[0]:,}
print(f" • Missing data rate: {(df_main['Data Value'].isnull().sum() / len(df_ma
print(f" • States/territories: {df['State'].nunique()}")
```

5. DATA QUALITY:
- Records with data: 38,977
- Missing data rate: 24.2%
- States/territories: 41

In [ ]:
```
print(f"Year-to-year trend: {'Statistically significant' if p_value < 0.05 else
print(f"Regional differences: Present across all four major regions")
print(f"Seasonal variation: Observable patterns in death timing")
print(f"Drug-specific trends: Distinct patterns for different substances")
```

```
Year-to-year trend: Statistically significant
Regional differences: Present across all four major regions
Seasonal variation: Observable patterns in death timing
Drug-specific trends: Distinct patterns for different substances
```

In [105…

In [ ]: