

Outsmarting Outbreaks

An Analytic Approach to West Nile Virus Prevention and Control In Chicago

Liyena | Marko | Munah | Tiffany

West Nile Virus Cases Increasing in the U.S.

Most cases of the mosquito-borne illness are concentrated in the West and Southwest, but officials across the East Coast have also raised concerns.



By Cecelia Smith-Schoenwalder | Sept. 18, 2023, at 2:36 p.m.

US: States issue alert over West Nile virus after New York City reports death

New York, United States • Edited By: Prisha • Updated: Sep 18, 2023, 09:15 PM IST



Colorado has most West Nile virus cases in U.S. so far this year, and it's not even close

Author: Jennifer Campbell-Hicks

Published: 1:57 PM MDT September 26, 2023

Updated: 1:57 PM MDT September 26, 2023



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Of the West Nile Virus

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WNV Cases in the US

24 Years

Since West Nile Virus
1st reported

55,443

Cases reported
from 1999 to 2021*

~7,000,000

Estimated infections
(including unreported)**

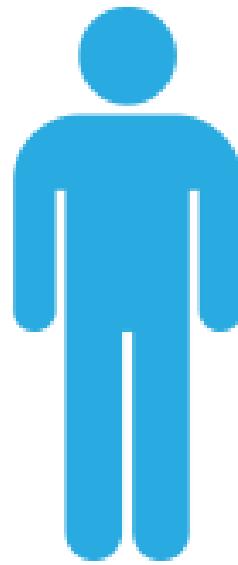
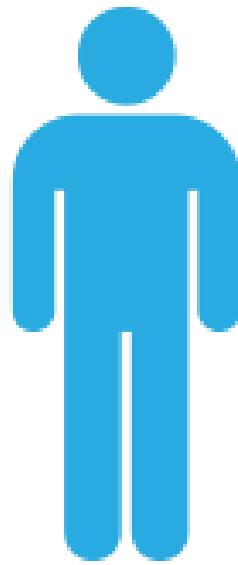
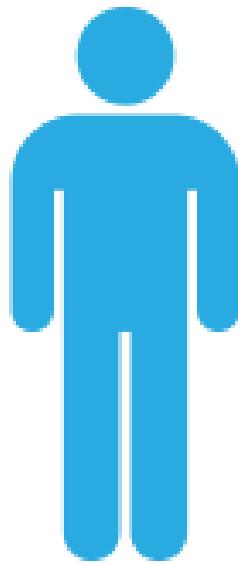
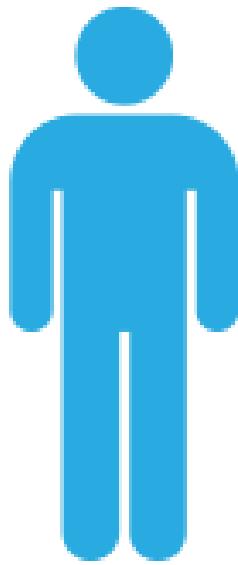
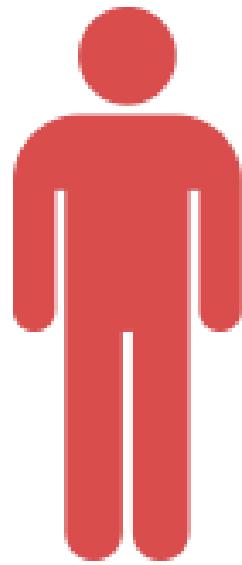
Source(s): *<https://www.epa.gov/climate-indicators/climate-change-indicators-west-nile-virus>

**<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8101735/#:~:text=In%20the%202020%20years%20since,million%20people%20have%20been%20infected>

A photograph of a cemetery at sunset. The sky is a warm orange and yellow. In the foreground and middle ground, there are numerous white crosses standing in rows on a green lawn. The crosses are evenly spaced and extend into the distance. Some crosses are partially in shadow, while others are brightly lit by the setting sun. In the background, there are more trees and a clear horizon.

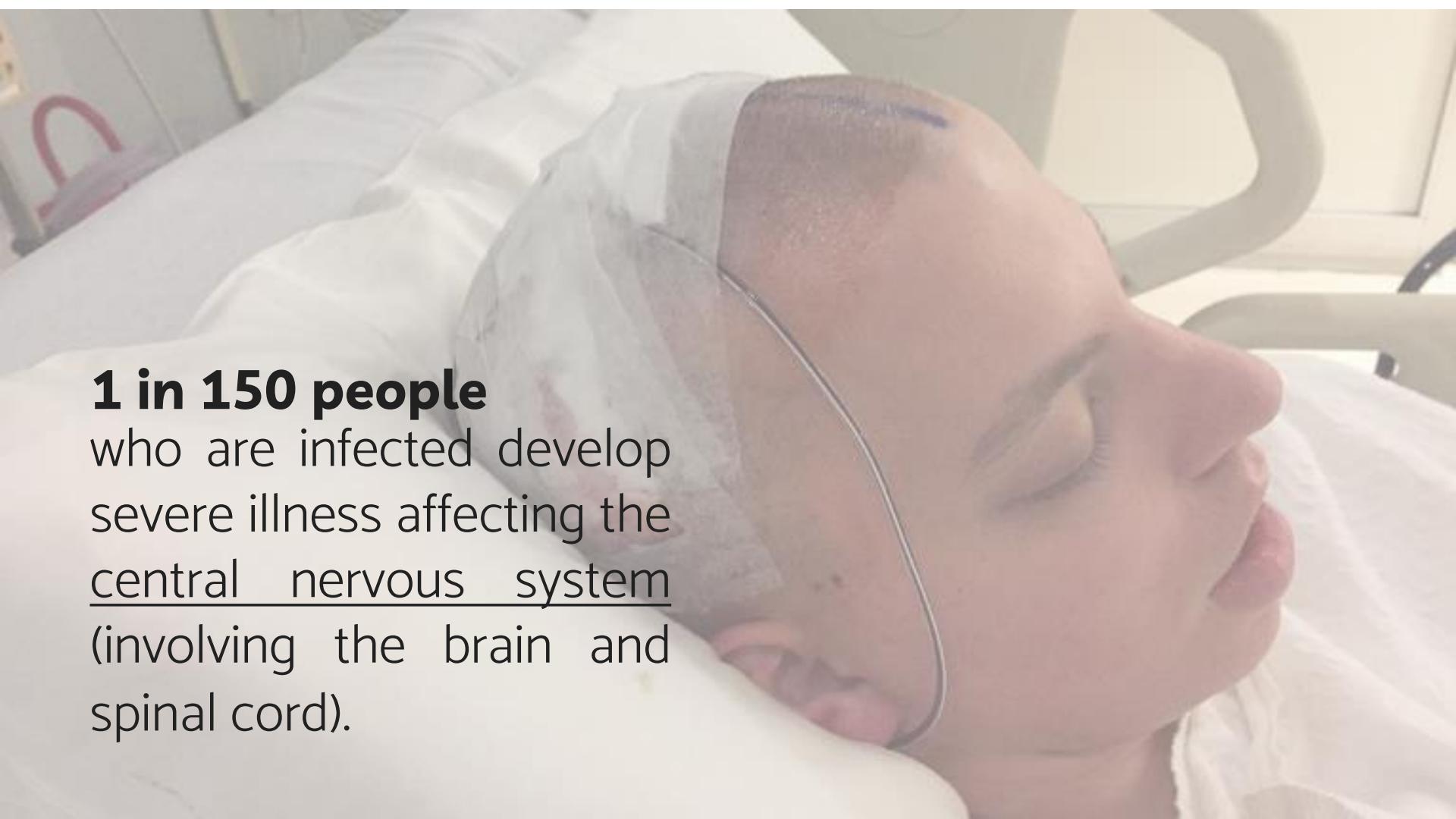
2 776 Deaths

From 1999 to 2022



1 in 5 people

who are infected has fever with other symptoms such as body aches, headache, diarrhea and rashes.



1 in 150 people

who are infected develop
severe illness affecting the
central nervous system
(involving the brain and
spinal cord).

WnV cases

In 2023

1 936
cases 

As of 17 October 2023*



1 255
neuroinvasive
West Nile disease cases 

WnV cases

In 2023

46

**States reported of WnV
cases in 2023**



> 18 deaths

In Aug and Sep 2023





FACTS ABOUT CULEX MOZZIES

Most active from
**DUSK TO
DAWN**

Thrive at
27 deg C

It takes
7 to 10 days
For an egg to develop into
an adult



Spraying of mosquito adulticides and larvicides

CURRENT MEASURES



Larvicide
briquettes
in catch
basins

The Chicago Department of Public Health aims to **optimize resource allocation** and improve public health outcomes by evaluating the impact of interventions, such as spraying, on reducing the prevalence of West Nile virus.

Success metrics: ROC-AUC score

Problem statement



DATA

02

Data

Train

12 columns

10 506 observations

7 species of mosquitoes

136 traps

Years 2007, 2009, 2011, 2013



Test

11 columns

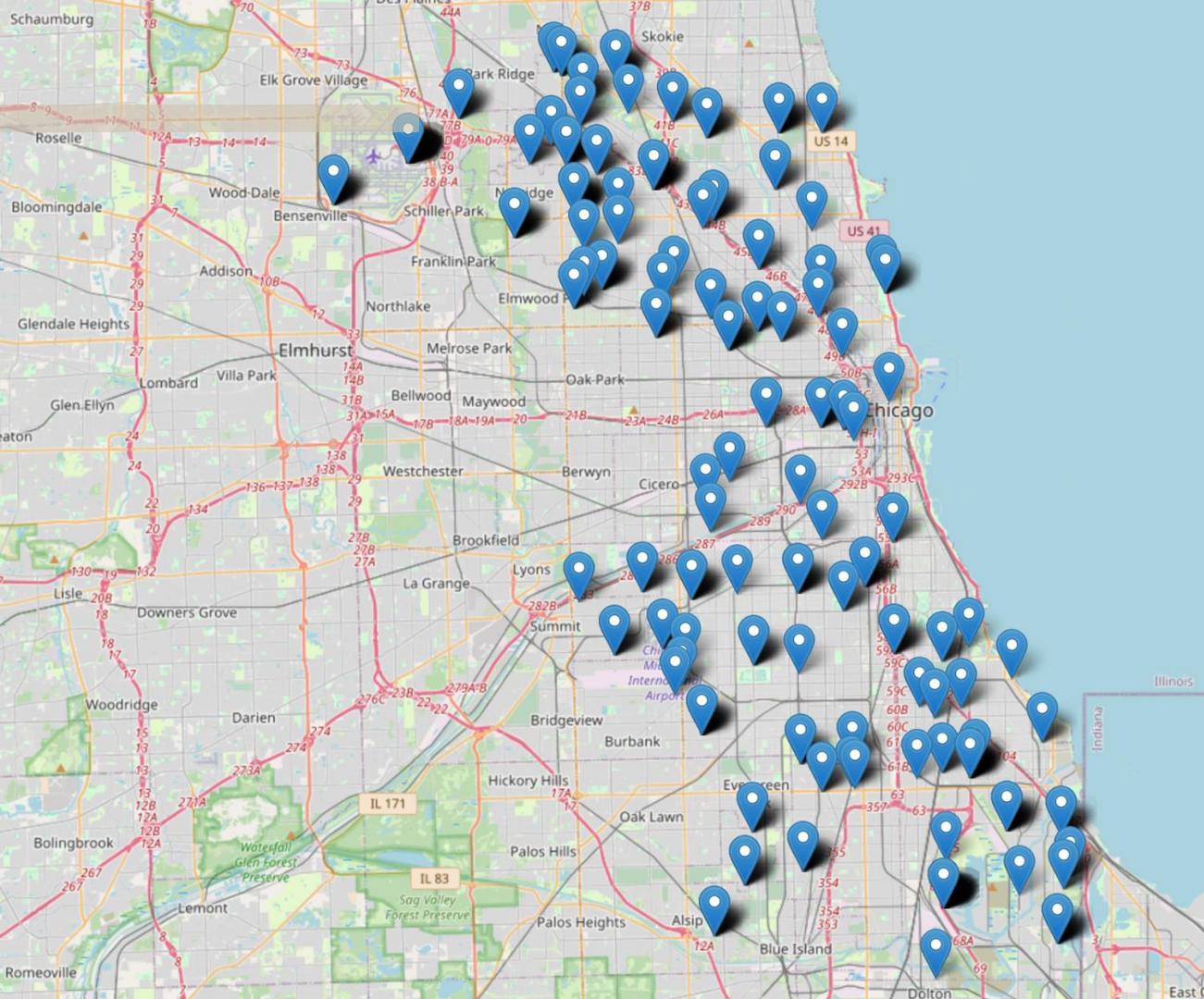
116 293 entries

8 species of mosquitoes

149 traps

Years 2008, 2010, 2012, 2014





Train Data: Mosquito Traps

from 2007, 2009, 2011, and 2013

- Trap Number
- Number of mosquitos
- Mosquito species
- Presence of West Nile Virus

Data



Spray



4 columns

14 835 entries

Years **2011** and **2013**

Weather



22 columns

2944 observations

2 stations

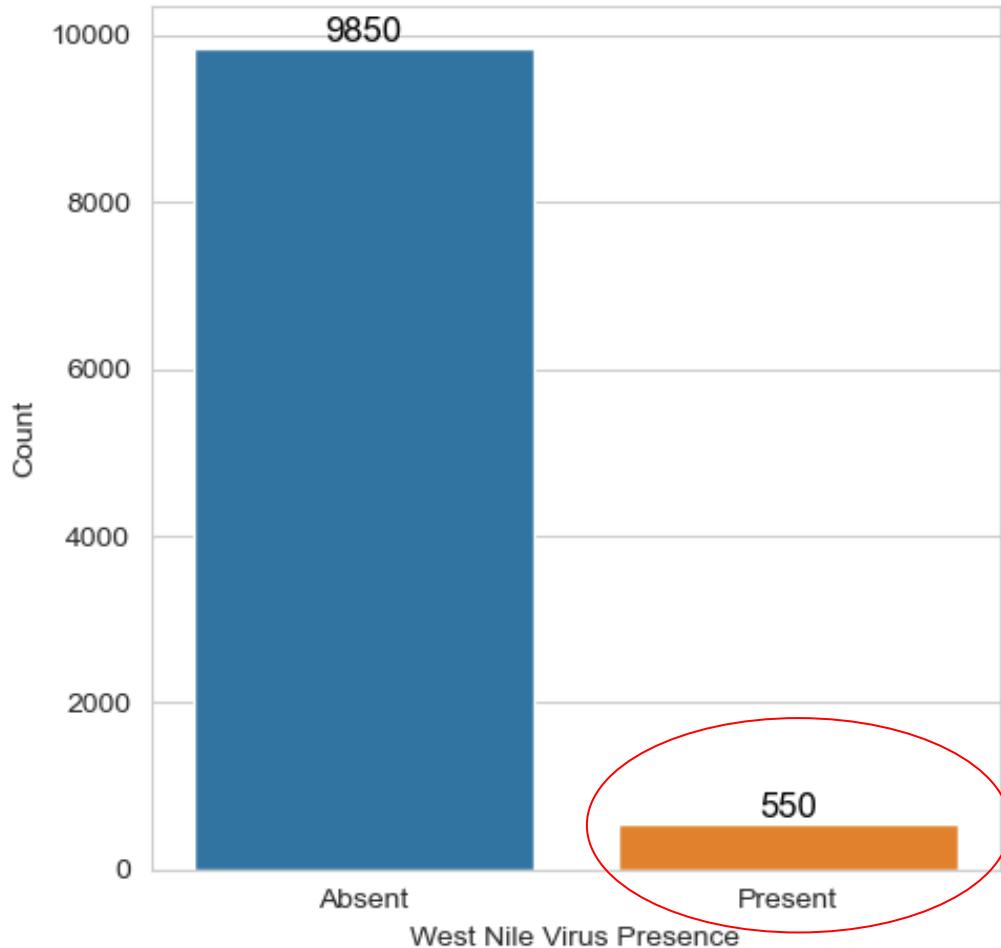
Years **2007** to **2014**

A black and white aerial photograph of the Chicago skyline, featuring the Willis Tower (formerly Sears Tower) and the Magnificent Mile along the Lake Michigan shore. The city extends into the distance under a cloudy sky.

DATA EXPLORATION

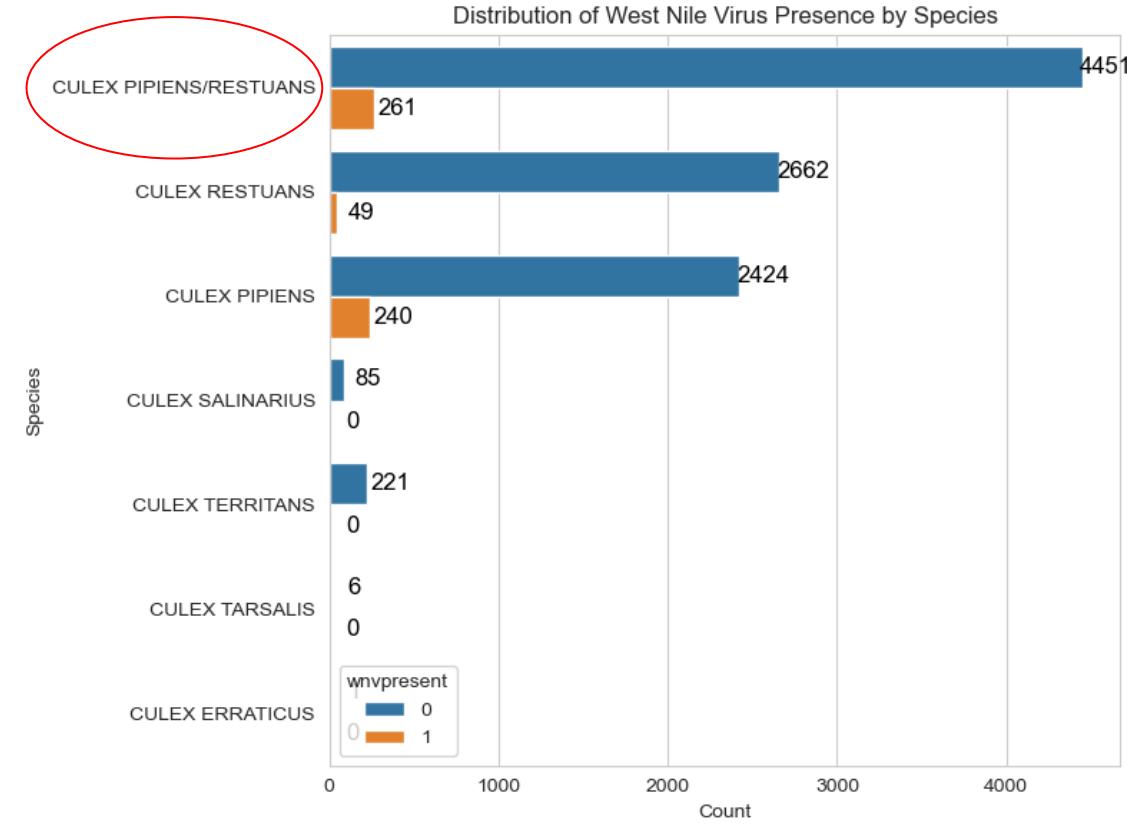
03

Distribution of West Nile Virus Presence



**IMBALANCED
PRESENCE OF
WNV**





CULEX PIPIENS AND RESTUANS

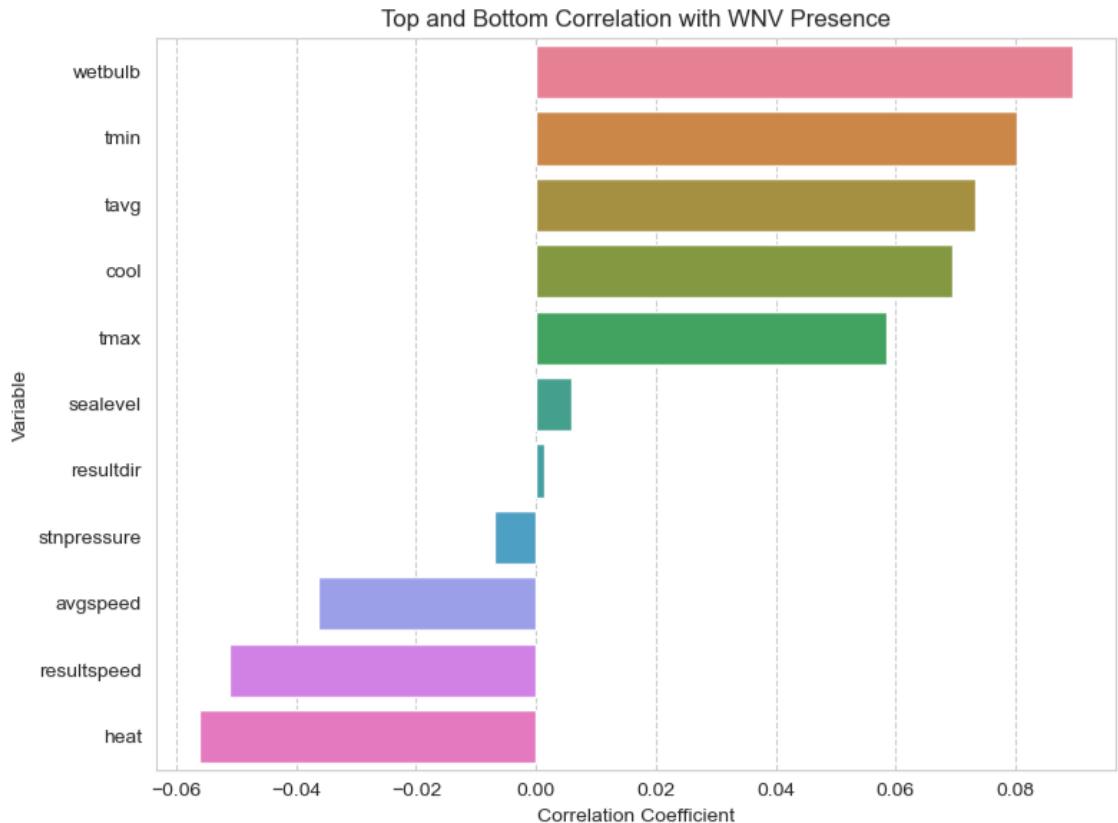


Hard to distinguish between the two subspecies of mosquitos.



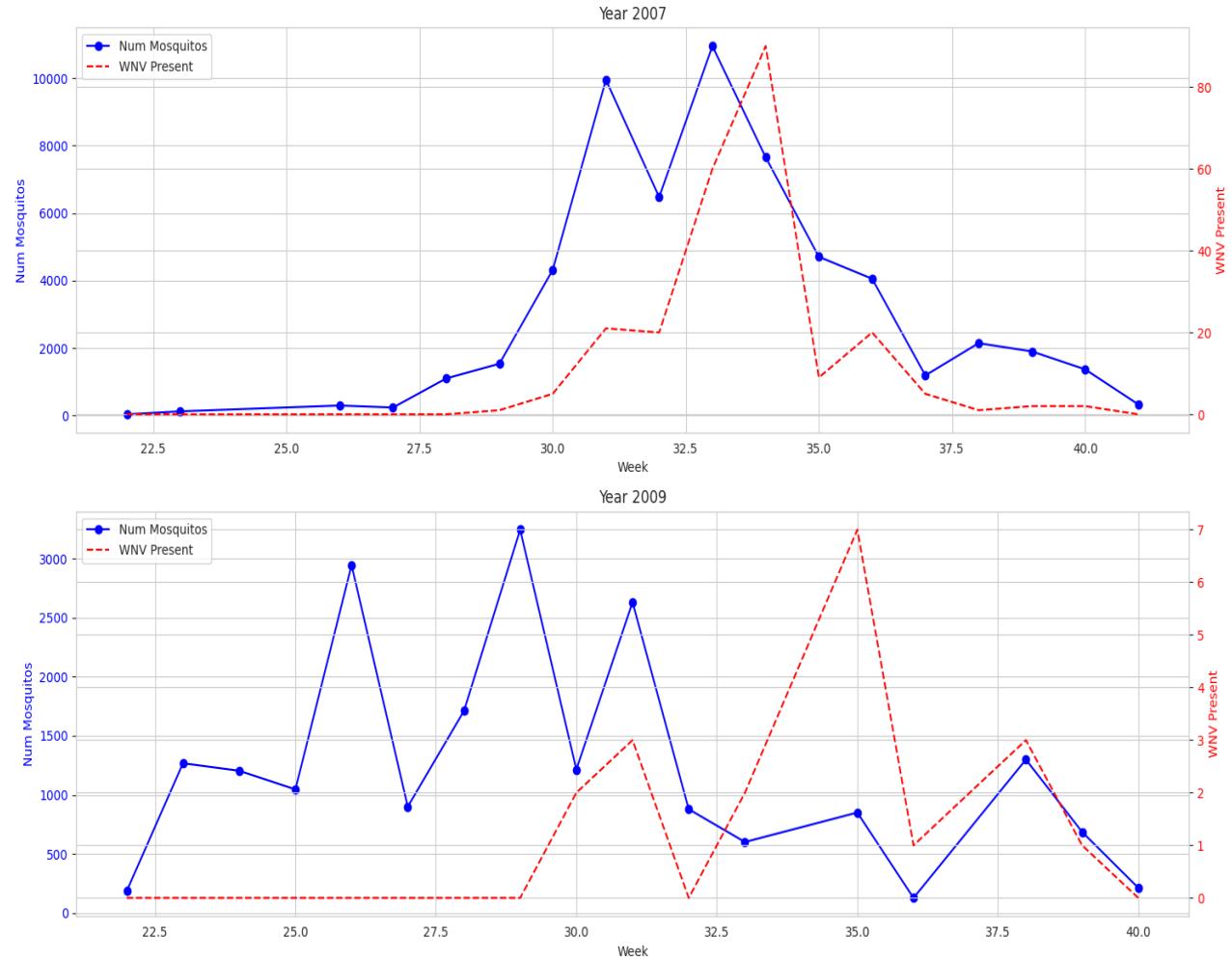
A

B



LITTLE
CORRELATIONS
BETWEEN THE
WEATHER
CONDITIONS
AND THE WNV
PRESENCE





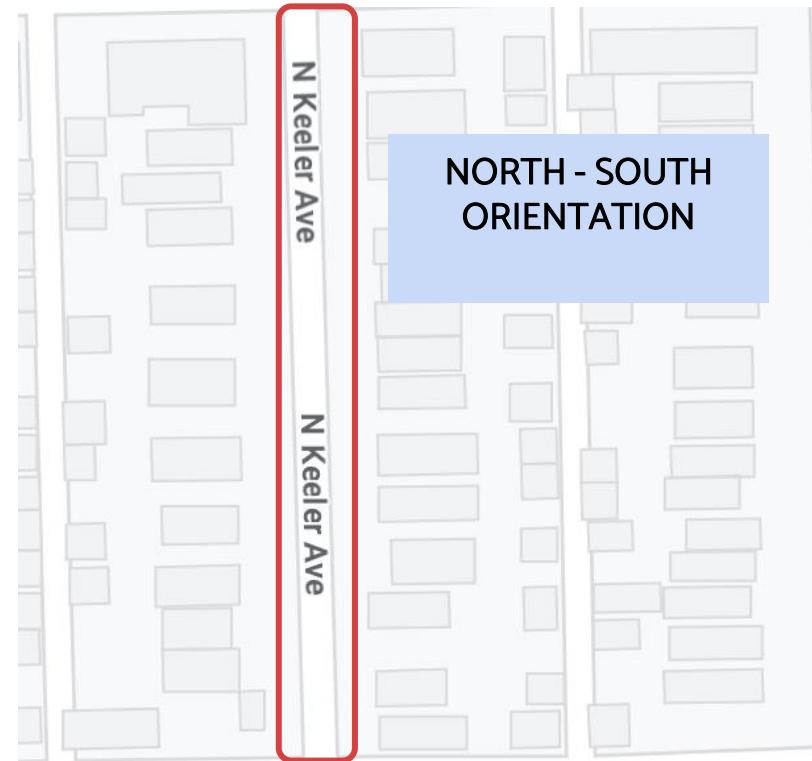
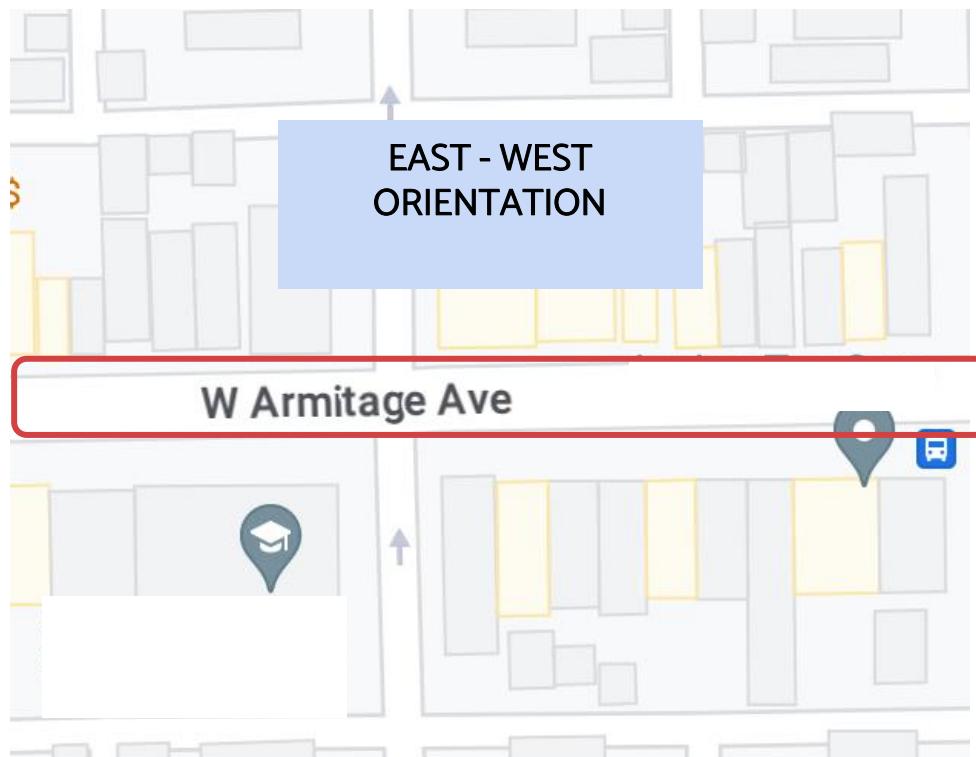
**SPIKE IN WNV
PRESENT,
A FEW WEEKS
AFTER HIGH
VOLUME OF
MOSQUITOS**

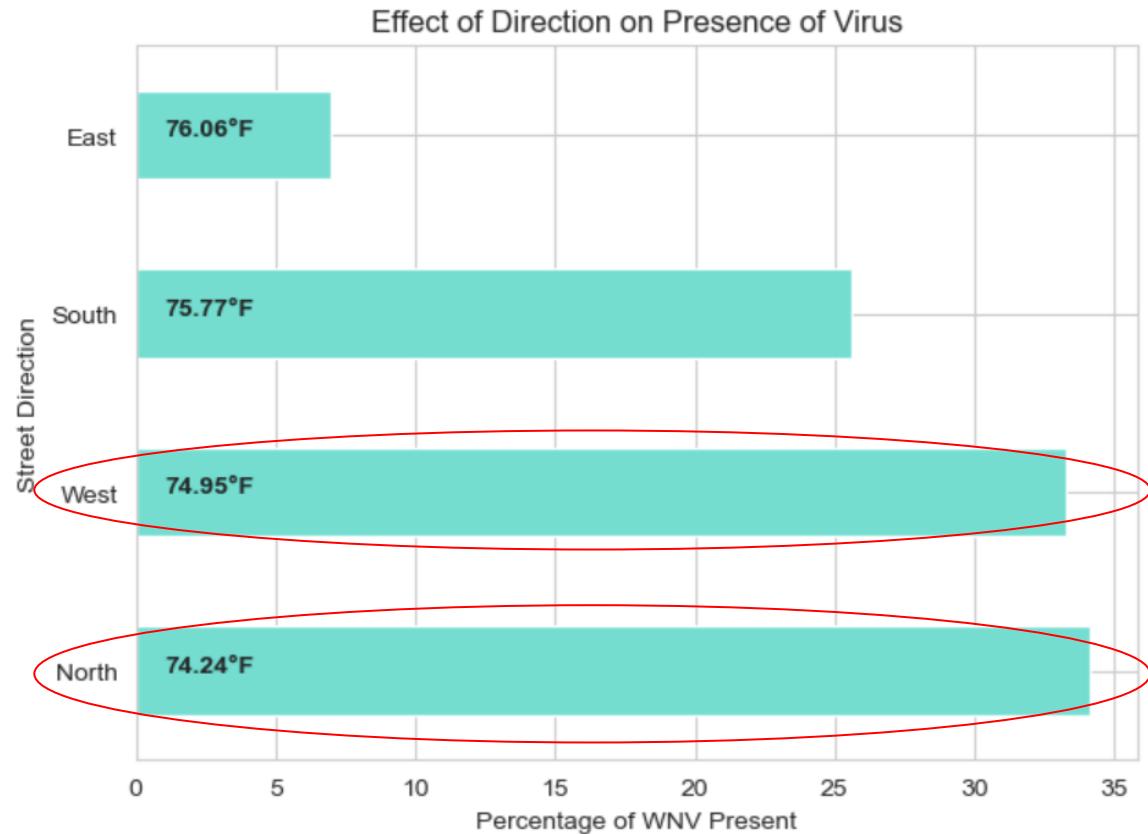


FEATURE ENGINEERING

Dataset	Original Feature	New Features	
train_df from train.csv	Street	Direction: {'N':0, 'W':1, 'S':2, 'E':3}	S STONY ISLAND AVE
	Date	Week (Week 1 to Week 52) Year DayofWeek (Mon to Sun)	W ARMITAGE AVENUE
	Species	Label encoded	
weather_df from weather.csv	ResultDir (direction of wind in degrees)	WindDir: N, E, W, S, NE, NW, SE, SW	

STREET DIRECTION





EFFECT OF DIRECTION ON TARGET

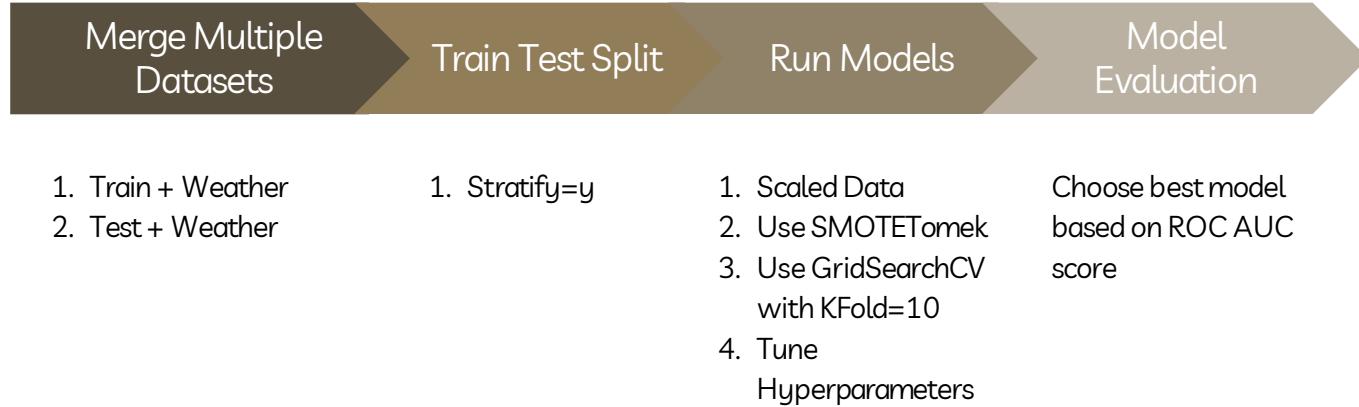




MODELLING

04

WORKFLOW

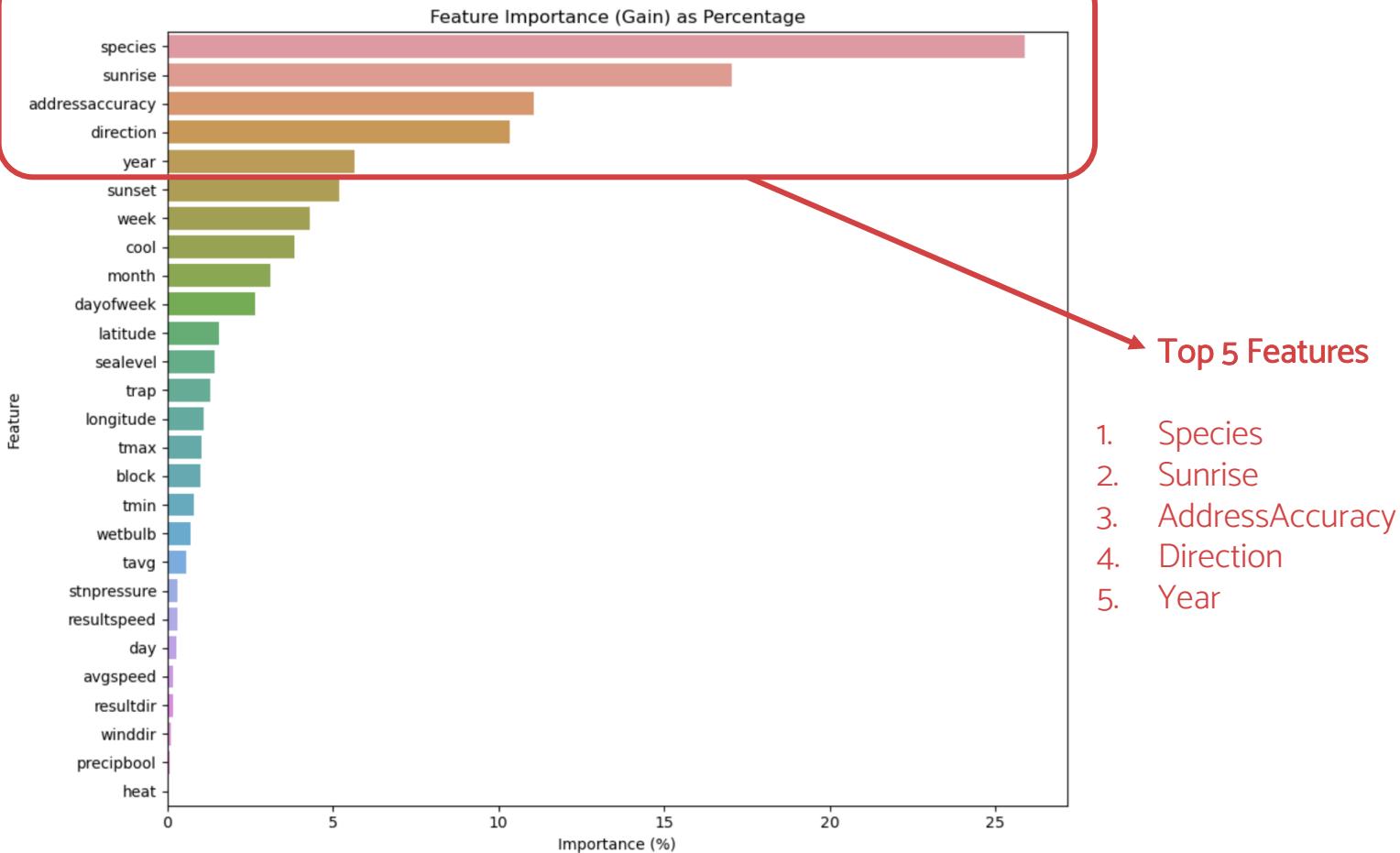


MODELS

PERFORMANCE METRICS: ROC-AUC Score

Model	Train	Test
Light GBM	0.88	0.84
XGBoost	0.95	0.85
Random Forest	0.99	0.84
K-Nearest Neighbors	0.96	0.82
Logistic Regression	0.80	0.80
Gaussian Naive Bayes	0.79	0.79
Decision Trees (Baseline)	0.89	0.78

FEATURE IMPORTANCE



CONCLUSION

- **Species:** Targeting breeding grounds of Culex Pipiens and Culex Restuans, known carriers of the West Nile virus, can reduce virus prevalence.
- **Sunrise:** Utilizing sunrise times to align spraying activities with peak mosquito activity (early morning) can enhance the effectiveness of interventions.
- **Direction:** Street orientation influences local wind and sunlight patterns, aiding in predicting mosquito breeding sites and virus outbreak locations.

COST BENEFIT ANALYSIS

\$

SO
S

COSTS

Cost of Spray = Cost of Spraying Per Area * Land Area * Frequency

- Cost of Spraying Zenivex E2O (Insecticide) per area = USD 0.67 / acre¹
- Total land area in Chicago = 148,300 acres
- No. of Sprays per year = 12
- **Total Cost of Spraying per year = USD 1.2MM**

Cost of Traps = No. of Traps * Cost of Each Trap

- No. of Traps (from dataset) = 149
- Median cost per Gravid Trap (incl maintenance) = 300 USD³
- **Total Cost of Traps per year = USD 45K**

Total Costs = USD 1.25MM

Source:

1:[Https://www.centralsmosquitoco.../zenivex-cost-comparison-fact-sheet.pdf](https://www.centralsmosquitoco.../zenivex-cost-comparison-fact-sheet.pdf)

2:<chrome-extension://efaidnbmnnibpcjpcgkclefindmkaj/><https://www.chicago.gov/content/dam/city/depts/cdph/Mosquito-Borne-Diseases/Zenivex.pdf>

3: <https://www.johnwhock.com/products/mosquito-sandfly-traps/cdc-gravid-trap/>

BENEFITS

Benefits are derived from the potential savings from **1) Loss in Productivity / Income, and 2) Medical Bills** if individuals are kept free from WnV

Total estimated costs for United States hospitalized West Nile virus cases and death from **1999 through 2012** by cost category from simulation model in 2012 USD

Cost category	Mean*	95% CI	Median*	Range
Total acute medical care	\$252,115,100	(\$158,022,000-\$458,998,400)	\$230,879,300	(\$115,644,400-\$2,822,846,000)
Total acute lost productivity [†]	\$22,081,260	(\$9,550,370-\$63,069,700)	\$16,144,050	(\$7,070,480-\$2,643,251,000)
Total long-term medical care	\$27,570,280	(\$11,566,780-\$56,221,870)	\$25,468,510	(\$6,087,800-\$118,883,900)
Total long-term lost productivity	\$26,866,800	(\$13,526,800-\$48,279,320)	\$25,416,720	(\$7,790,800-\$85,567,700)
Total lifetime lost productivity caused by deaths [‡]	\$449,464,800	(NA)	\$449,464,800	(NA)

- Cumulative Loss in Productivity + Medical Bills from 1999 to 2012 = **USD 787 MM**
- **Potential Savings per year = USD 56 MM**

OVERALL COST BENEFIT ANALYSIS

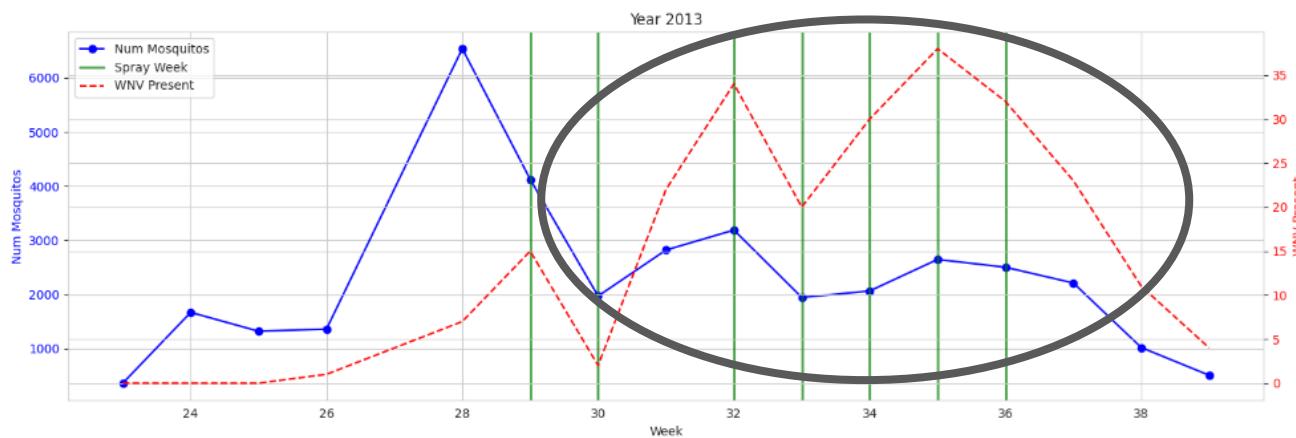
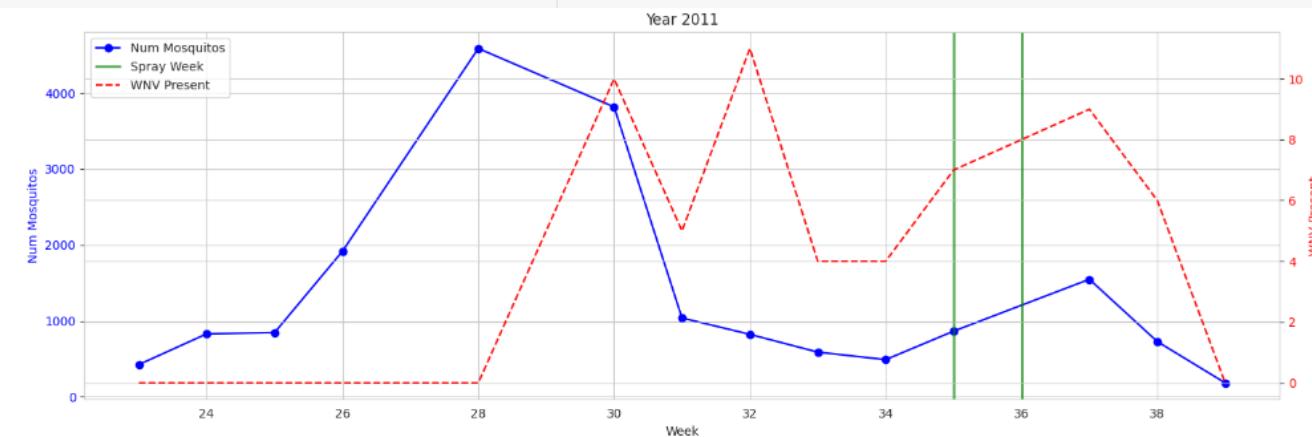
<i>Per Year</i>	CURRENT APPROACH	MODEL DRIVEN APPROACH
COST OF SPRAYING	-1.2 MM USD (entire Chicago)	-0.0052 MM USD (5% Chicago)
COST OF TRAPS	-0.045 MM USD	-0.045 MM USD
BENEFITS FROM MEDICAL BILLS + PRODUCTIVITY	+56MM USD	+56MM USD
NET BENEFIT	+55MM USD	+56MM USD



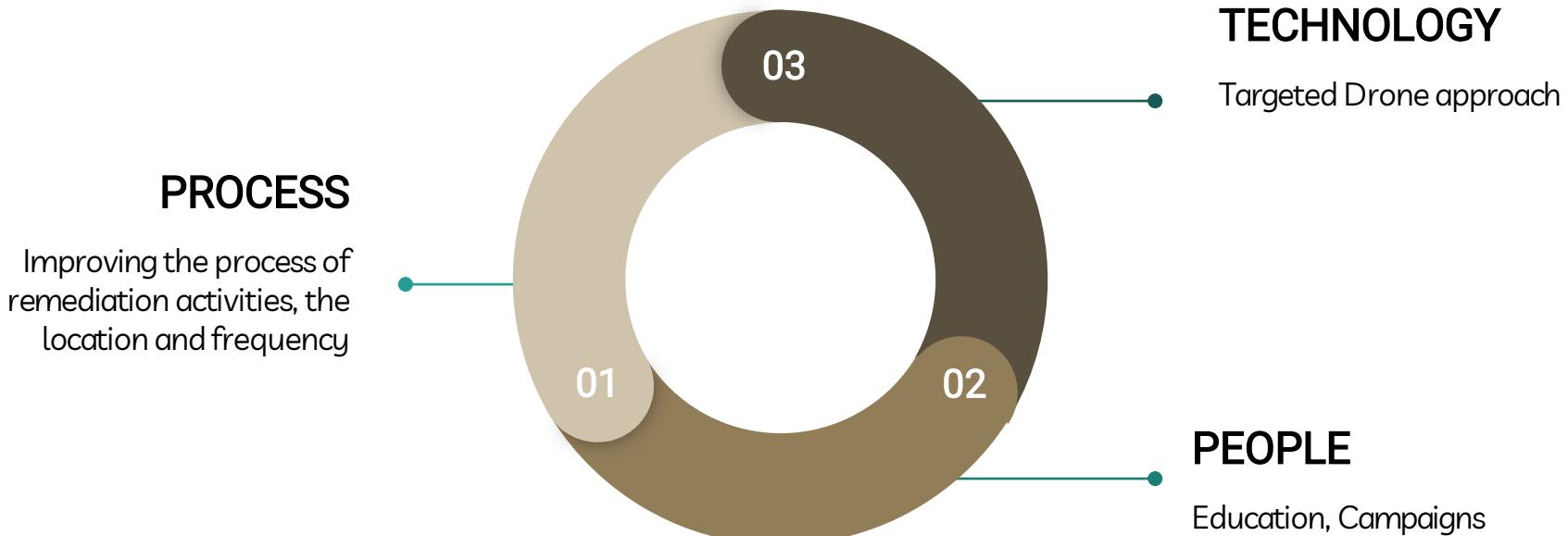
RECOMMENDATIONS



CURRENT SPRAYING APPROACH HAS *MINIMAL IMPACT*

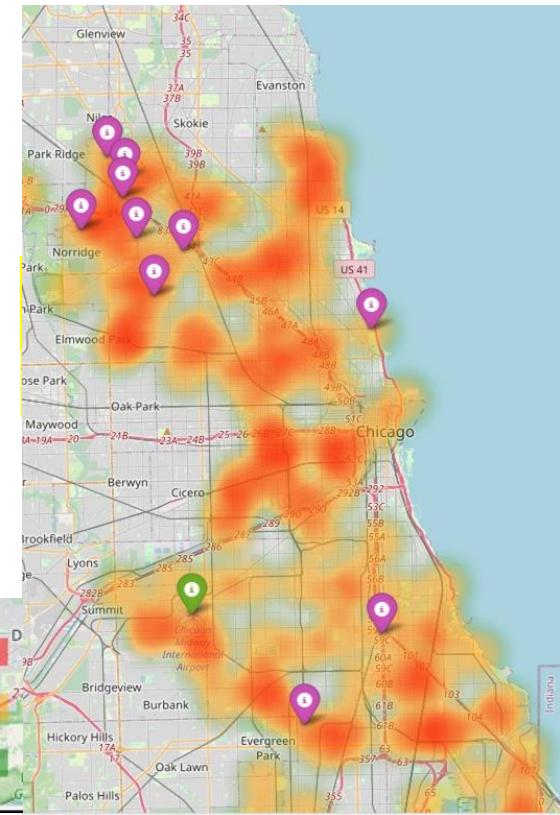
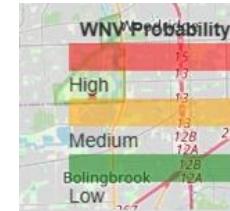


MULTI-PRONG APPROACH TO COMBAT WnV



1. PROCESS: TARGETED TIERED RESPONSE BASED ON WnV PROBABILITY

Probability of WnV in area	Frequency of activities	Public Education	Traps	Spray
< 5%	<i>Bi-monthly</i>	✓	✓	
5-10%	<i>Bi-monthly</i>	✓	✓	✓
10-15%	<i>Monthly</i>	✓	✓	✓
>15%	<i>Bi-weekly</i>	✓	✓	✓



2. MORE DRAMATIC AND IMPACTFUL PUBLIC EDUCATION / CAMPAIGNS

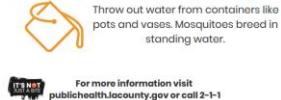
Current posters used in Chicago's battle against WnV:



Protect yourself and your loved ones



Cover or clear out standing water



Singapore's battle against Dengue:



3. LEVERAGING TECHNOLOGY: DRONE SPRAYS

- Higher Agility:
 - More targeted approach than mass spraying
 - Able to access areas that are not possible via foot
- More Eco-Friendly:
 - Less environmental impact than driving trucks / helicopters to spray
 - Less wastage of sprays

A photograph of a large bridge structure, likely the Manhattan Bridge, featuring tall towers and a walkway. The image is partially obscured by a dark, semi-transparent rectangular overlay containing the text.

Thank You

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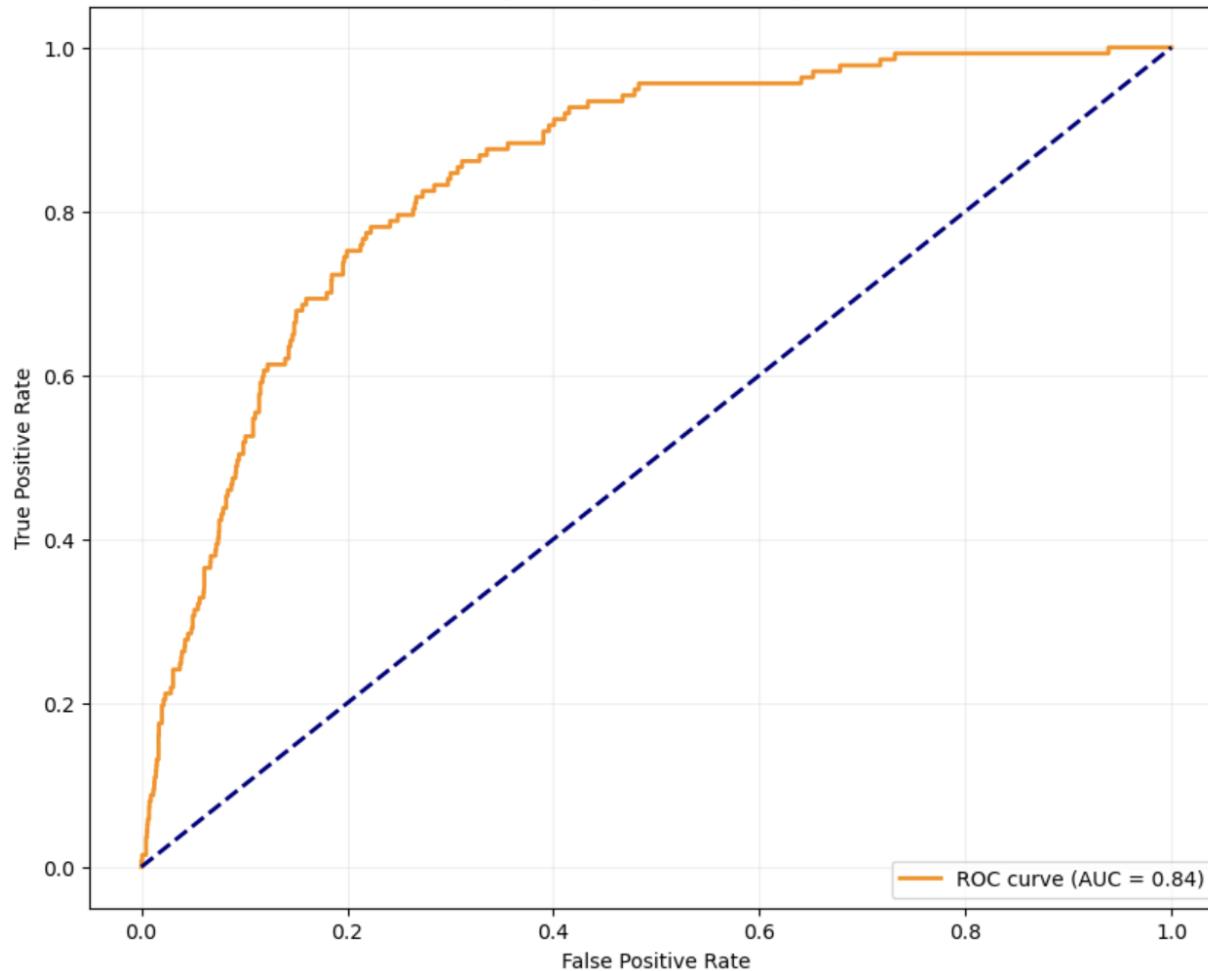
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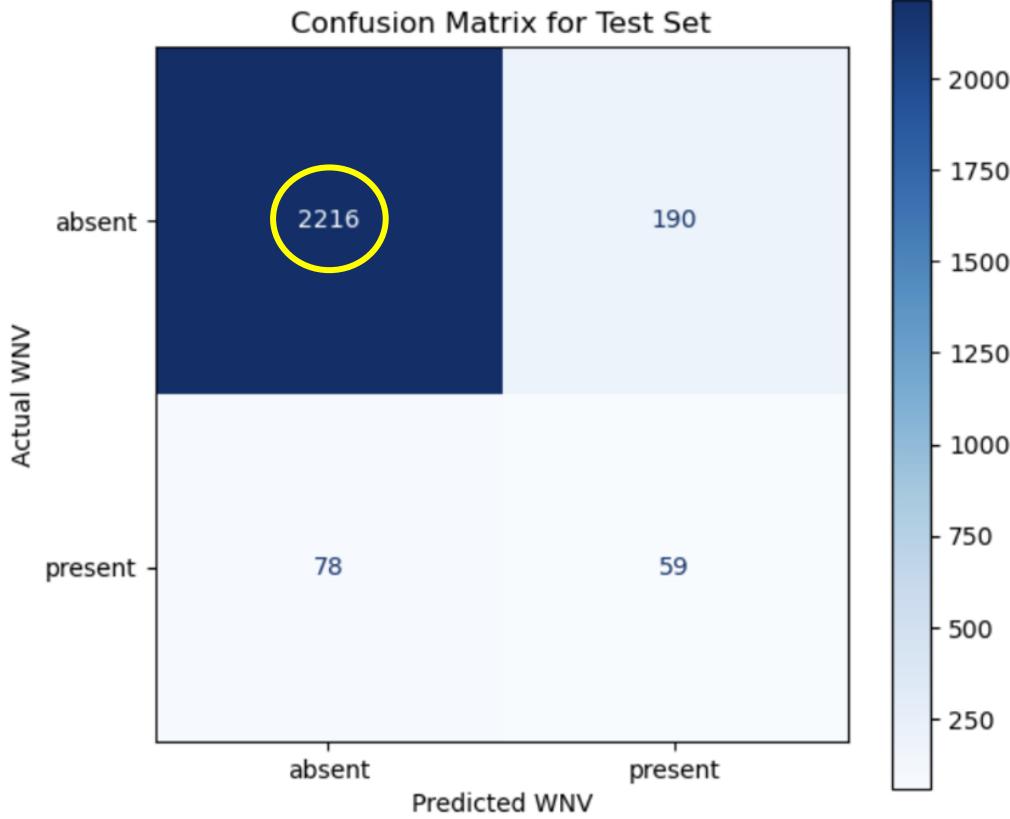


ROC AUC Score

Receiver Operating Characteristic (ROC) Curve



CONFUSION MATRIX



THANKS

