Outsmarting Outbreaks

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

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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%2020%20years%20since,million%20people%20have%20been%20infected

How bad is WnV?

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).

2 776 deaths
From 1999 to 2002

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%2020%20years%20since,million%20people%20have%20been%20infected
https://www.cdc.gov/westnile/statsmaps/historic-data.html

WnV cases

In 2023

1 936 cases

As of 17 October 2023*

→

1 255 neuroinvasive

West Nile disease cases

Source: https://www.cdc.gov/westnile/statsmaps/current-season-data.html

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

Source(s): https://www.mosquitomagnet.com/articles/when-are-mosquitoes-most-active
https://www.cdc.gov/mosquitoes/about/life-cycles/culex.html

CURRENT MEASURES

Aerial spraying of mosquito adulticides and larvicides

Larvicide briquettes in catch basins

Source(s): https://www.cdc.gov/westnile/vectorcontrol/aerial-spraying.html#:~:text=Aerial%20spraying%20uses%20very%20low,pollinating%20insects%20are%20not%20active.
https://www.chicago.gov/city/en/depts/cdph/provdrs/healthy_communities/news/2023/august/coc-spraying-for-mosquitoes-aug-1.html#:~:text=In%20addition%20to%20spraying%20adult,is%20an

Problem statement

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.

DATA

02

Data

Train

12 columns

10 506 observations

7 species of mosquitoes

136 traps

Years **2009, 2011, 2013, 2015**

Test

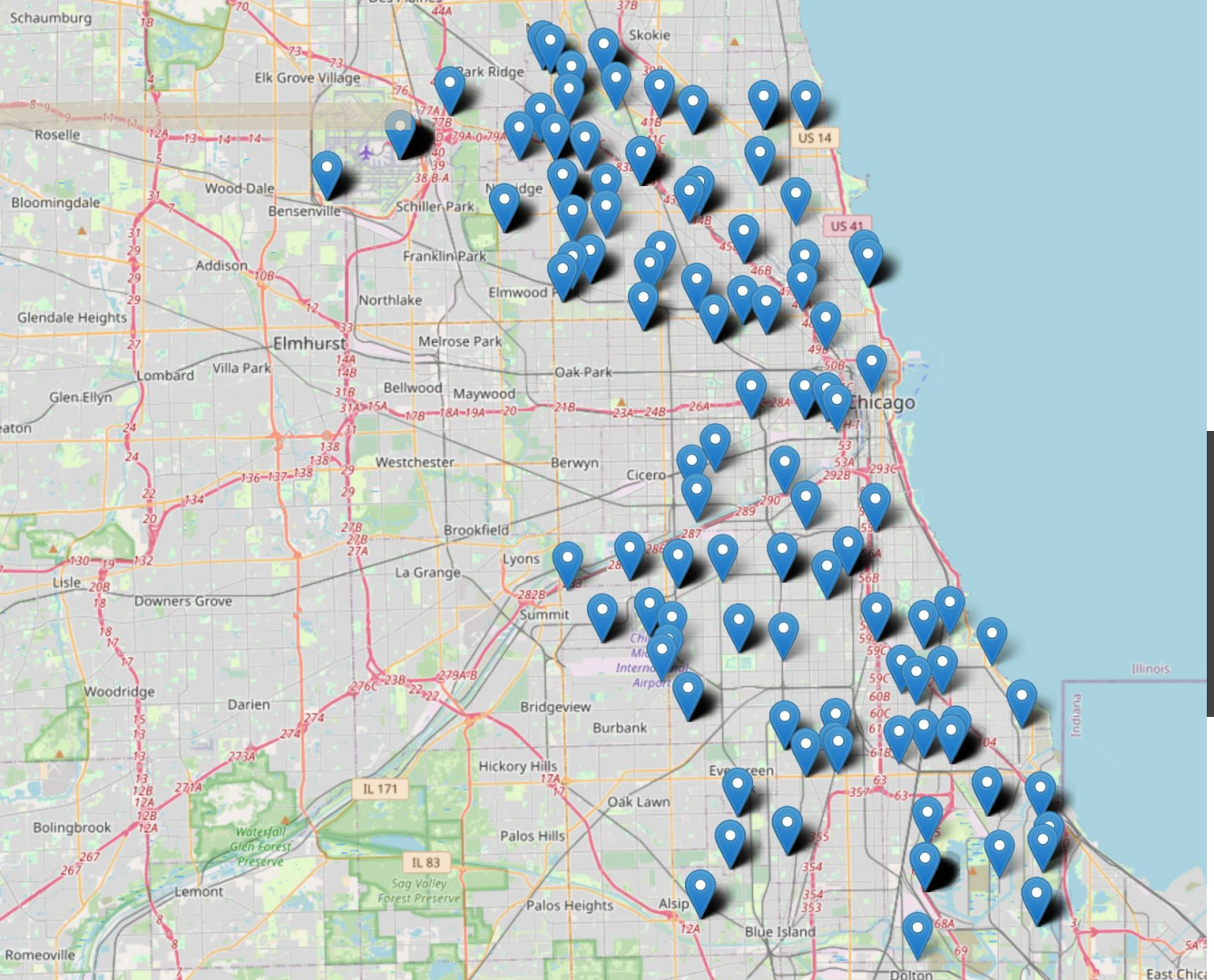
11 columns

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

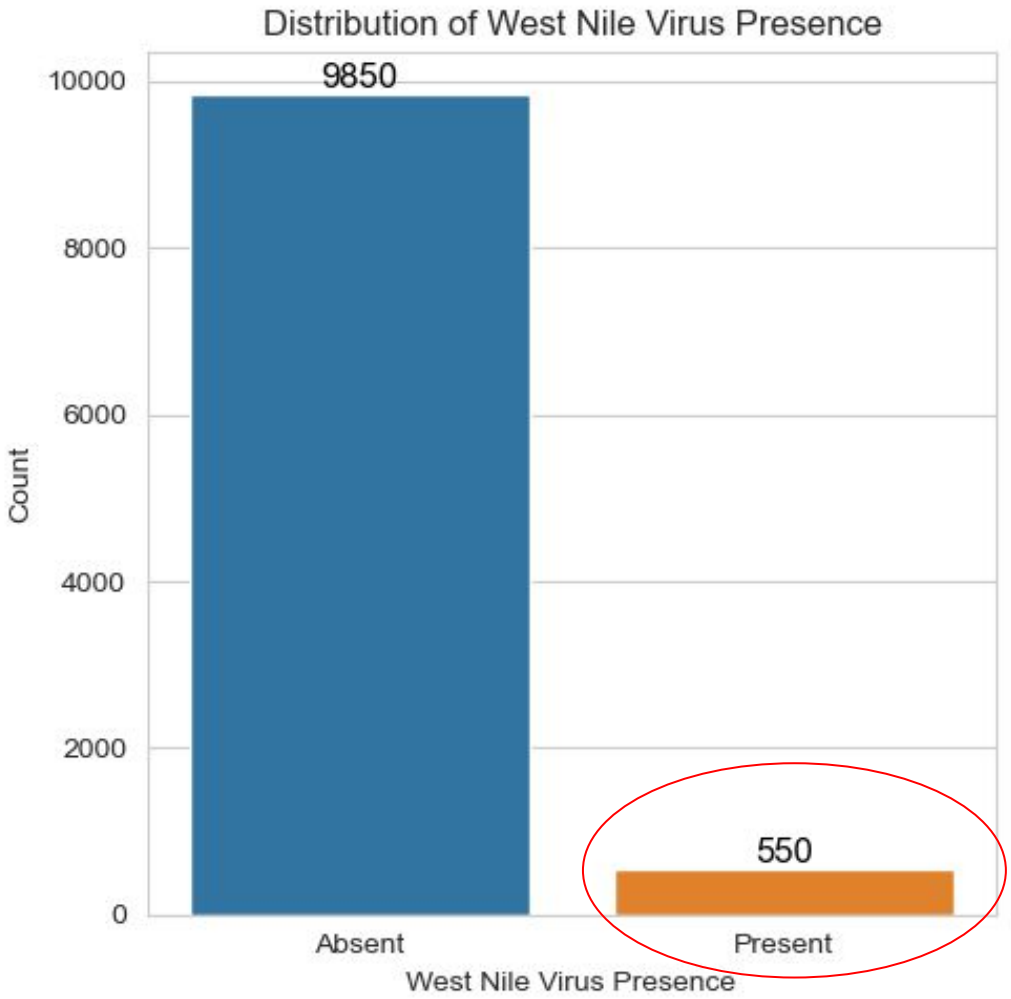
2944 observations

2 stations

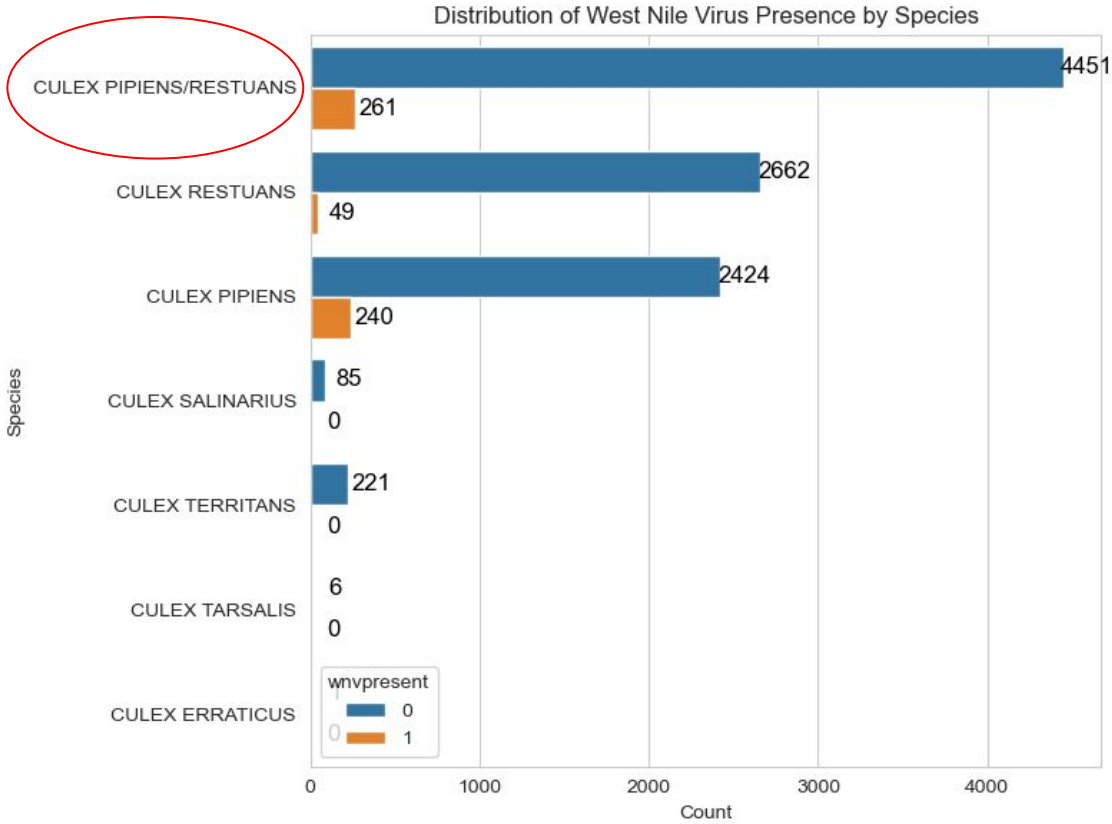
Years **2007 to 2014**

DATA EXPLORATION

03



IMBALANCED PRESENCE OF WNV

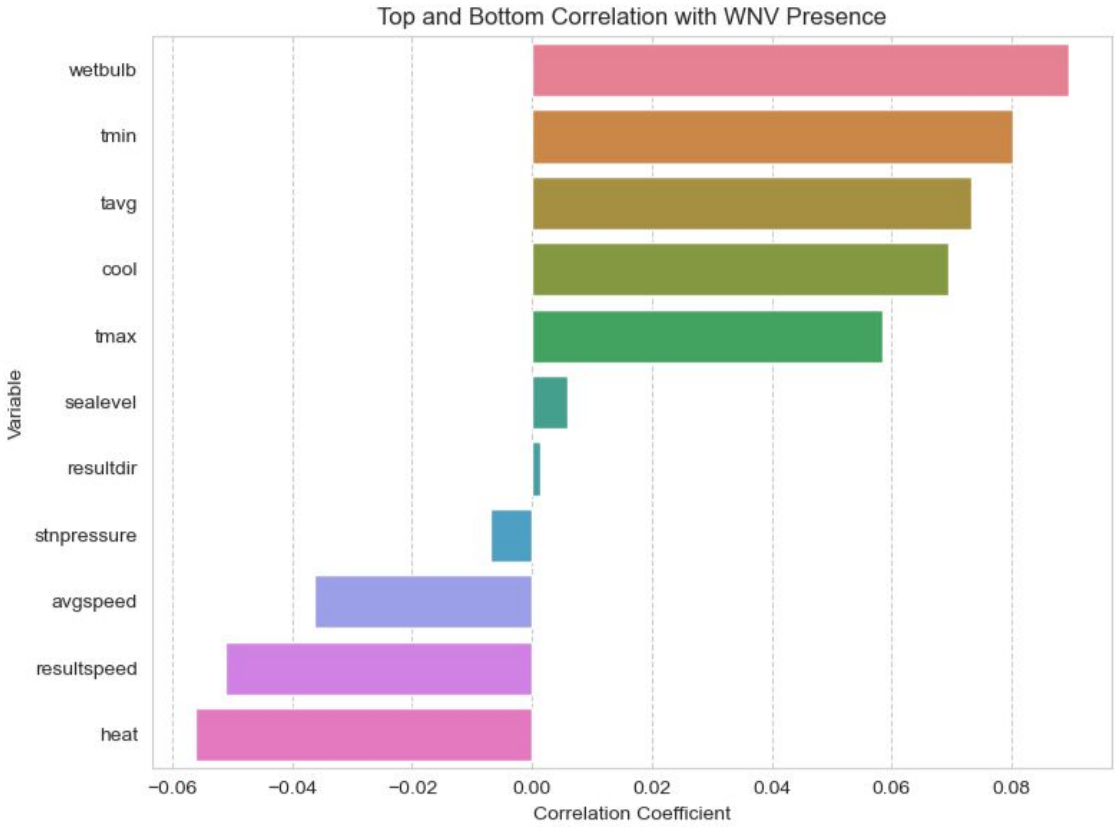


CULEX PIPIENS AND RESTUANS

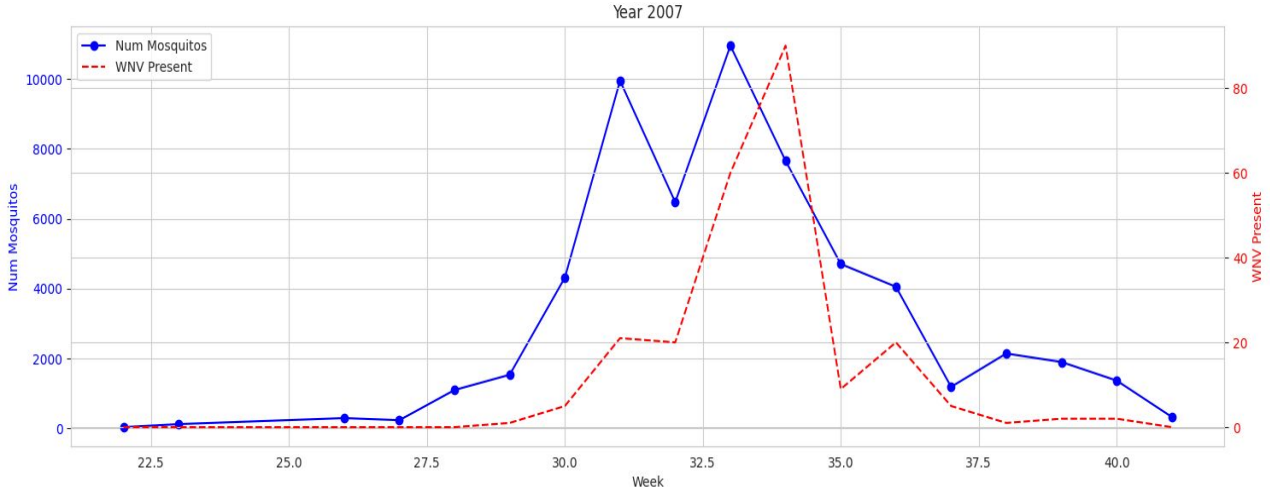
Hard to distinguish between the two subspecies of mosquitos.

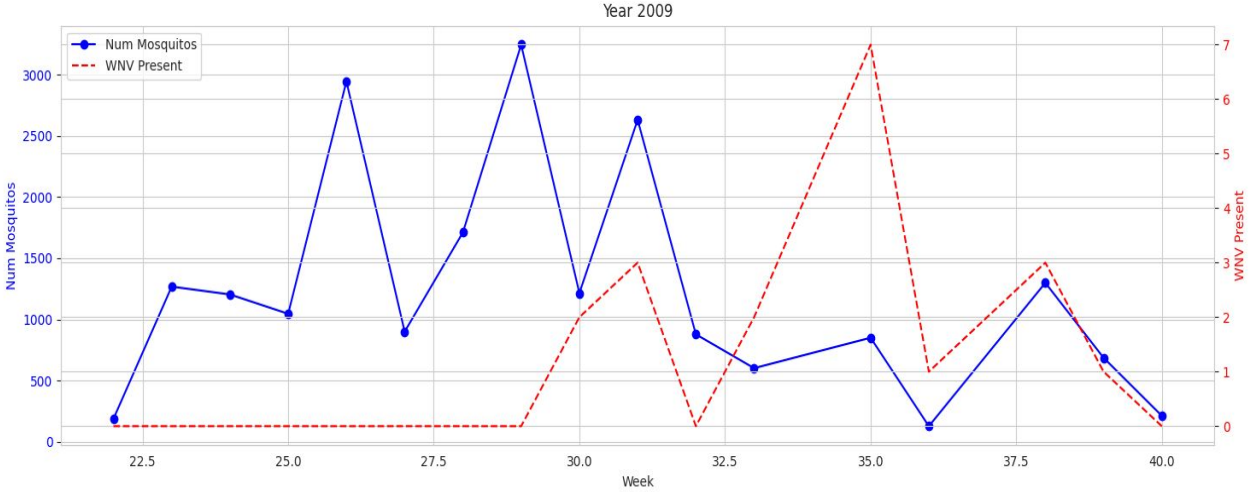
A

B



LITTLE CORRELATIONS BETWEEN THE WEATHER CONDITIONS AND THE WNV PRESENCE

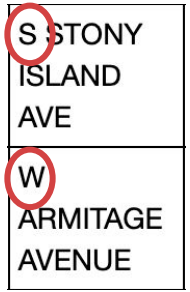




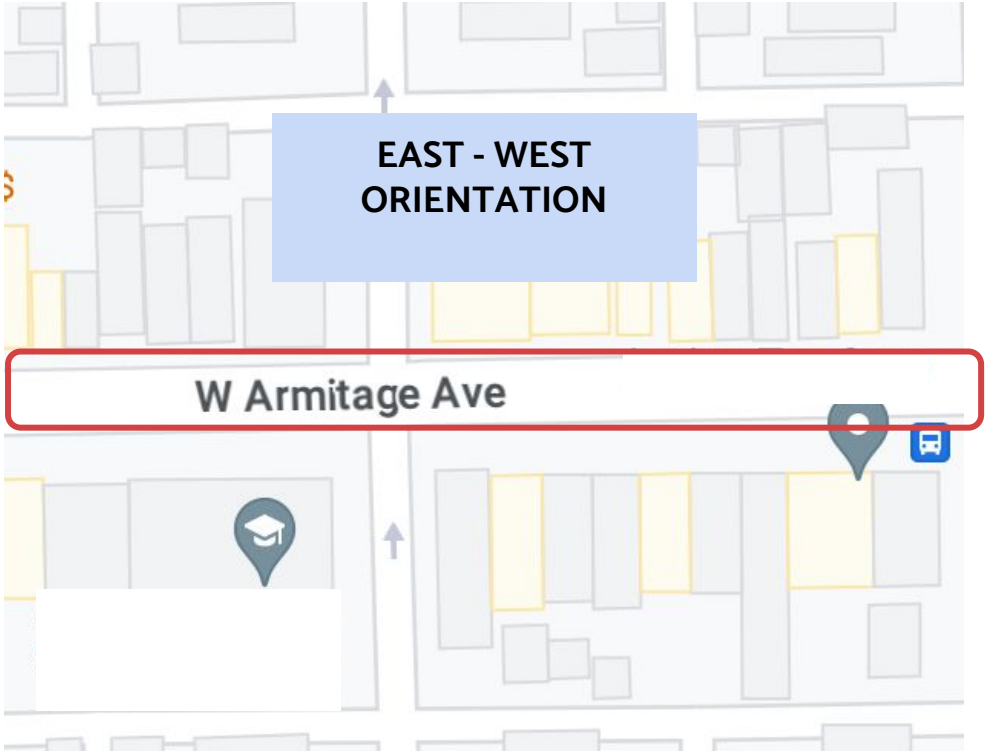
SPIKE IN WNV PRESENT, A FEW WEEKS AFTER HIGH VOLUME OF MOSQUITOS

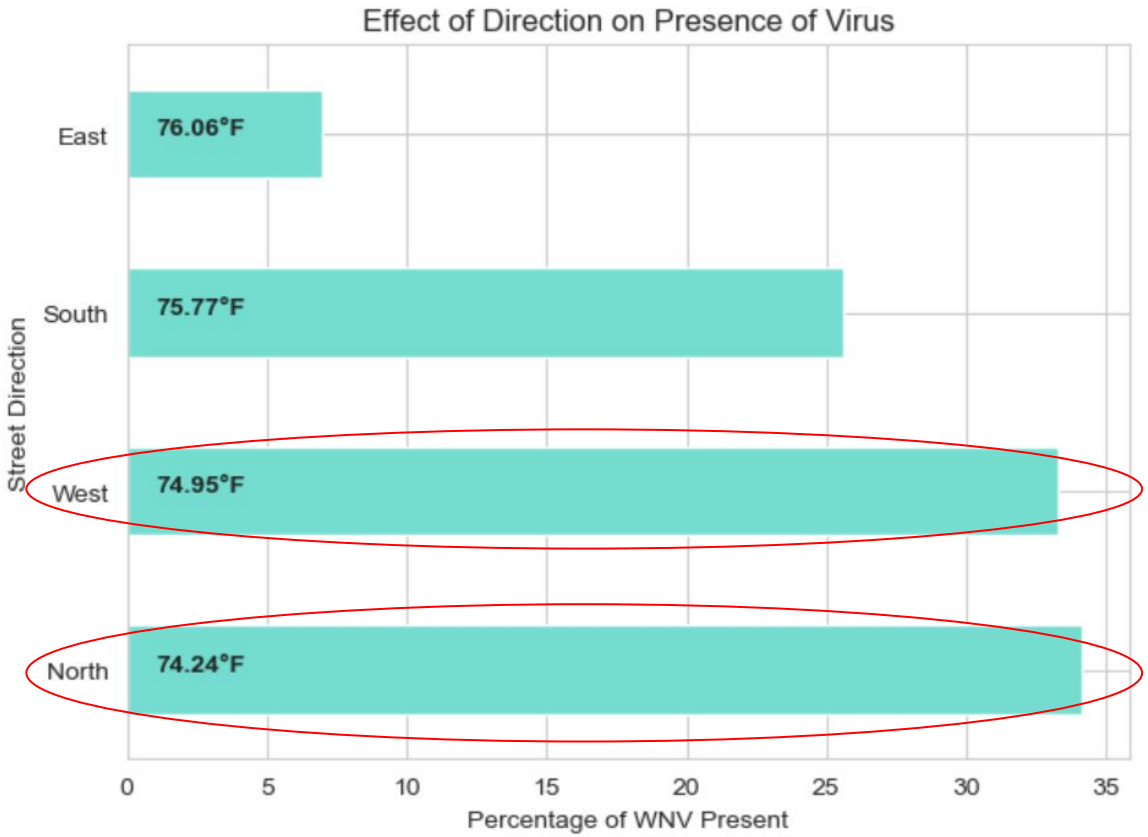
FEATURE ENGINEERING

Dataset	Original Feature	New Features
train_df from train.csv	Street	Direction: {'N':0, 'W':1, 'S':2, 'E':3}
	Date	Week (Week 1 to Week 52) Year DayofWeek (Mon to Sun)
	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

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WORKFLOW

1. Train + Weather
2. Test + Weather

1. Stratify=y

1. Use SMOTETomek
2. Use GridSearchCV with KFold=10
3. Tune Hyperparameters

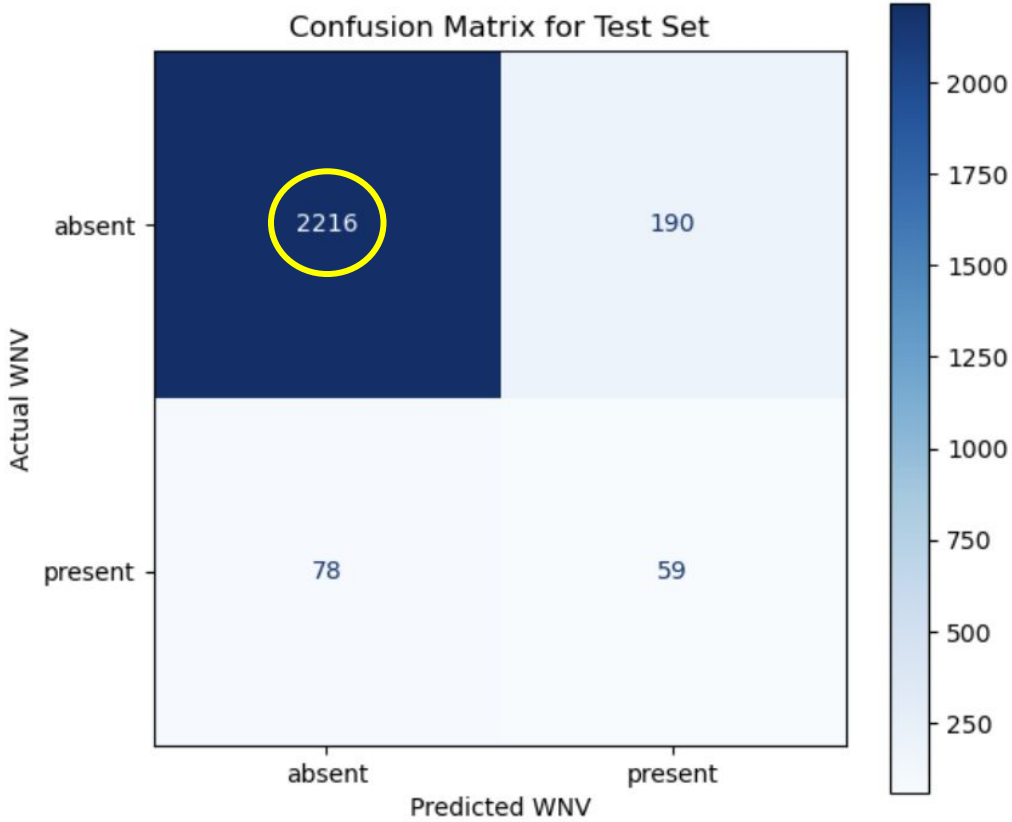
Choose best model based on ROC AUC score

MODELS

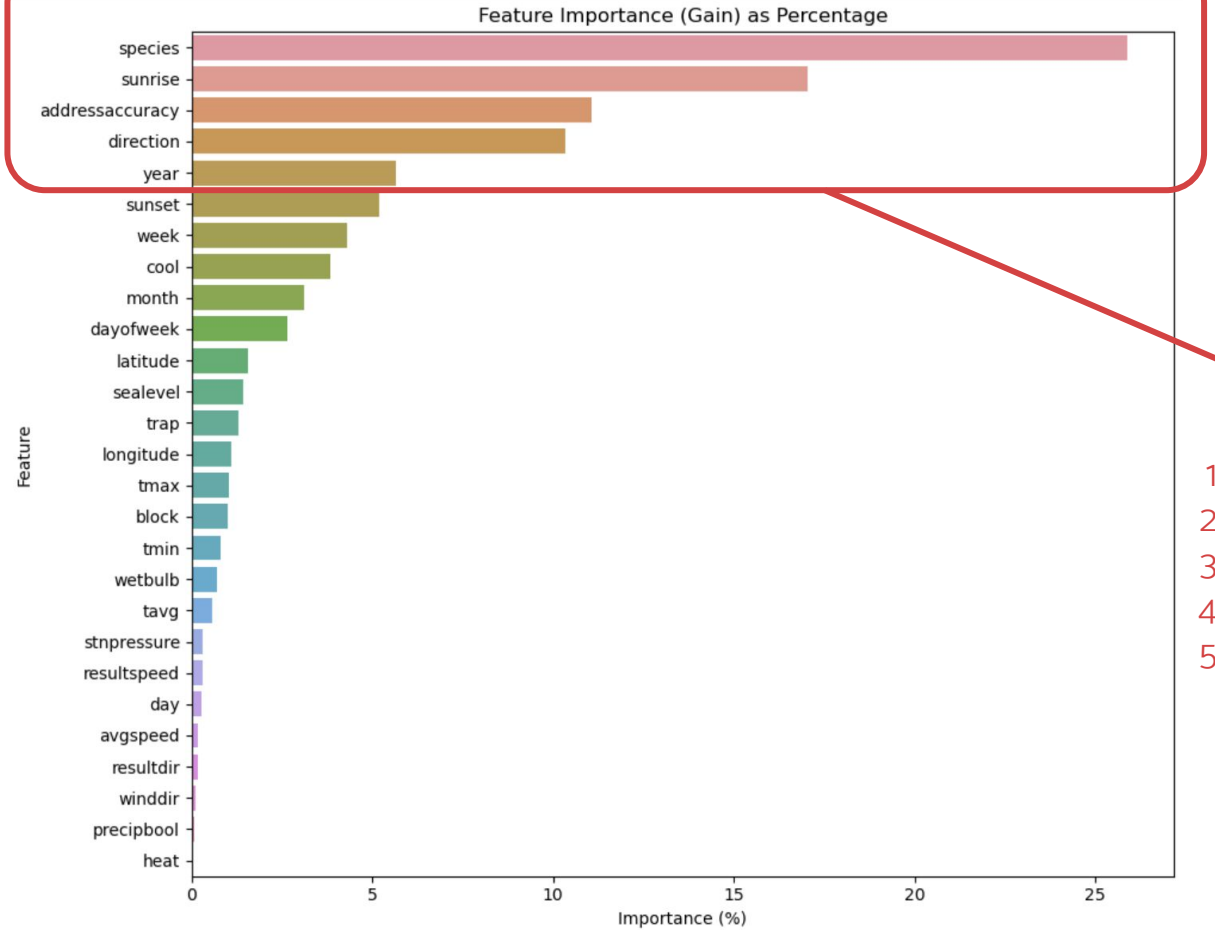
PERFORMANCE METRICS: ROC-AUC Score

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

CONFUSION MATRIX



FEATURE IMPORTANCE



Top 5 Features

1. Species
2. Sunrise
3. AddressAccuracy
4. Direction
5. Year

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 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

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COSTS

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

- Cost of **Spraying Zenivex E20 (Insecticide)** per area = **USD 0.67 / acre**[1]
- 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 USD[3]
- **Total Cost of Traps per year = USD 45K**

Total Costs = USD 1.25MM

Source:
1:Https://www.centralmosquitocontrol.com/-/media/project/oneweb/centralmosquitocontrol/files/us/resources-lit-files/zenivex-cost-comparison-fact-sheet.pdf
2:chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/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**

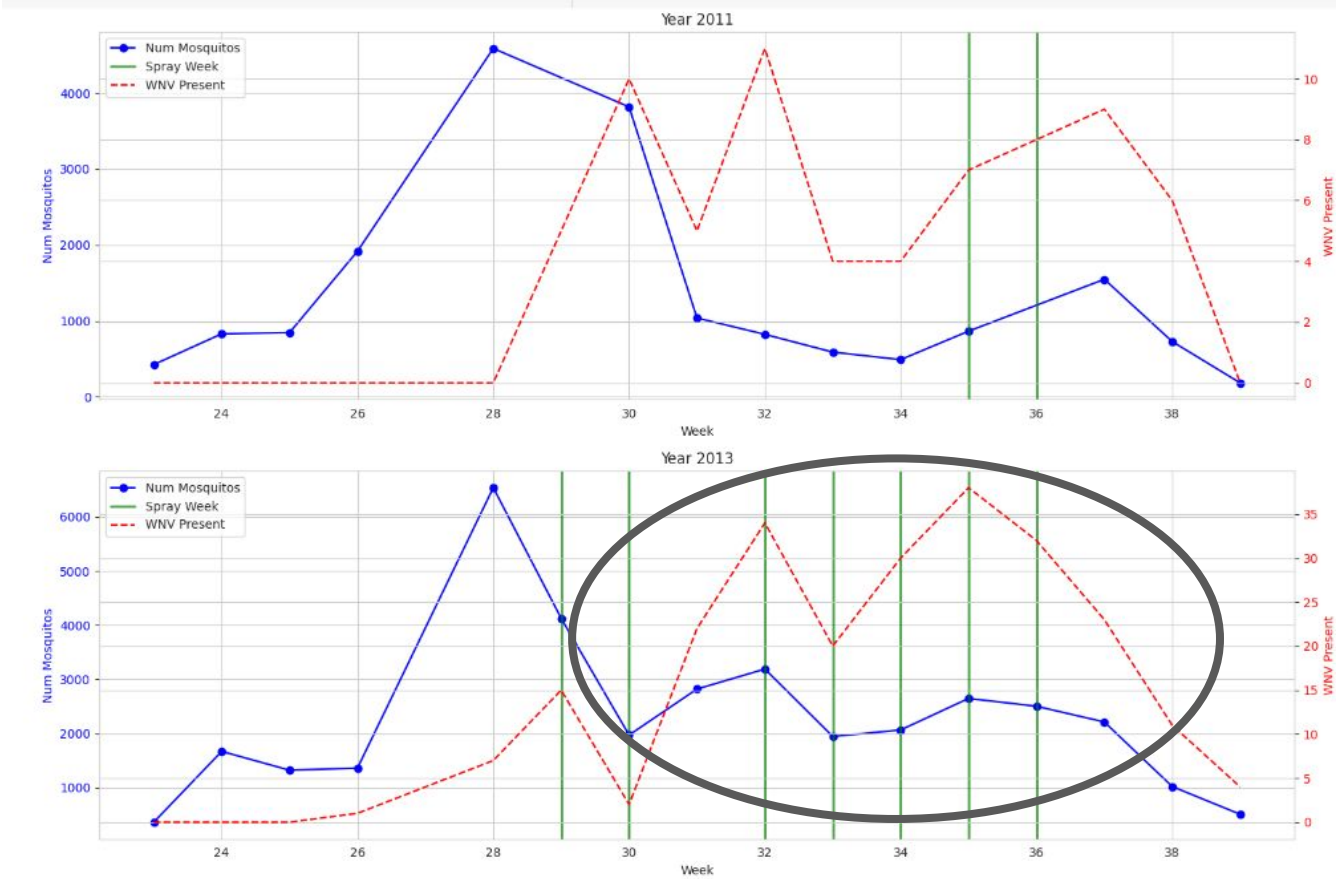
Source:
1: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3945683/

OVERALL COST BENEFIT ANALYSIS

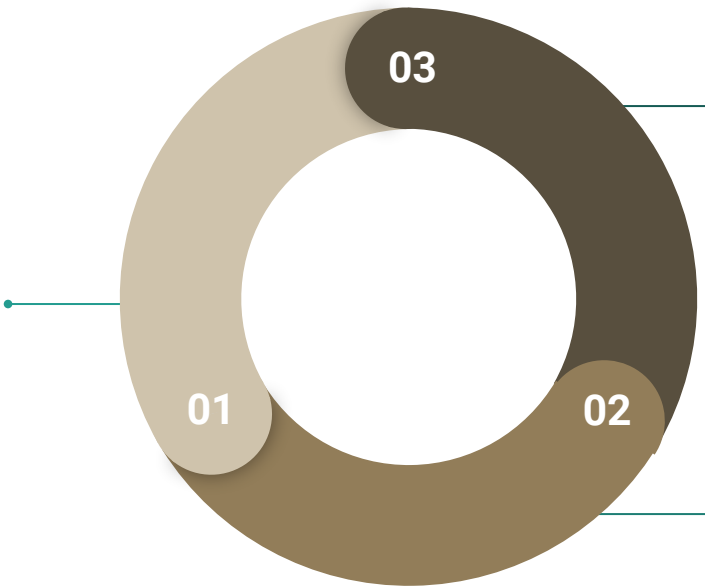
Per Year	CURRENT APPROACH	MODEL DRIVEN APPROACH
COST OF SPRAYING	-1.2 MM USD (entire Chicago)	-0.0052 MM USD (5% Chicago)
COST OF TRAPS	-0.045 MM USD	-0.045 MM USD
BENEFITS FROM MEDICAL BILLS + PRODUCTIVITY	+56MM USD	+56MM USD
NET BENEFIT	+55MM USD	+56MM USD

RECOMMENDATIONS

CURRENT SPRAYING APPROACH HAS *MINIMAL* IMPACT



MULTI-PRONG APPROACH TO COMBAT WnV



TECHNOLOGY

Targeted Drone approach

PROCESS

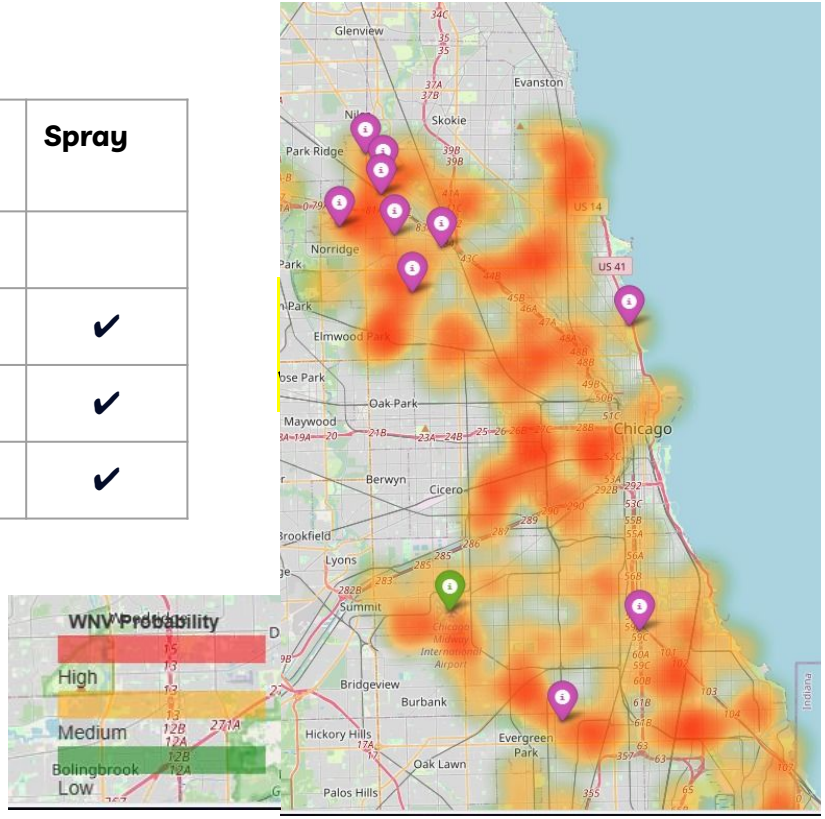
Improving the process of remediation activities, the location and frequency

PEOPLE

Education, Campaigns

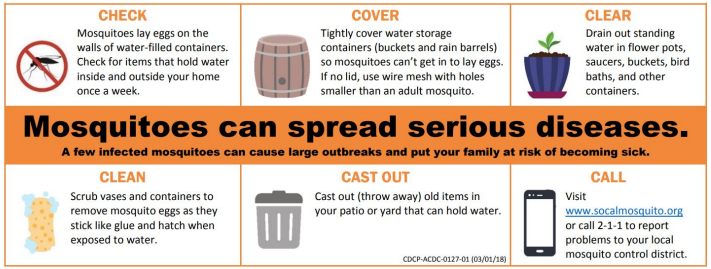
1. PROCESS: TARGETED TIERED RESPONSE BASED ON WnV PROBABILITY

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



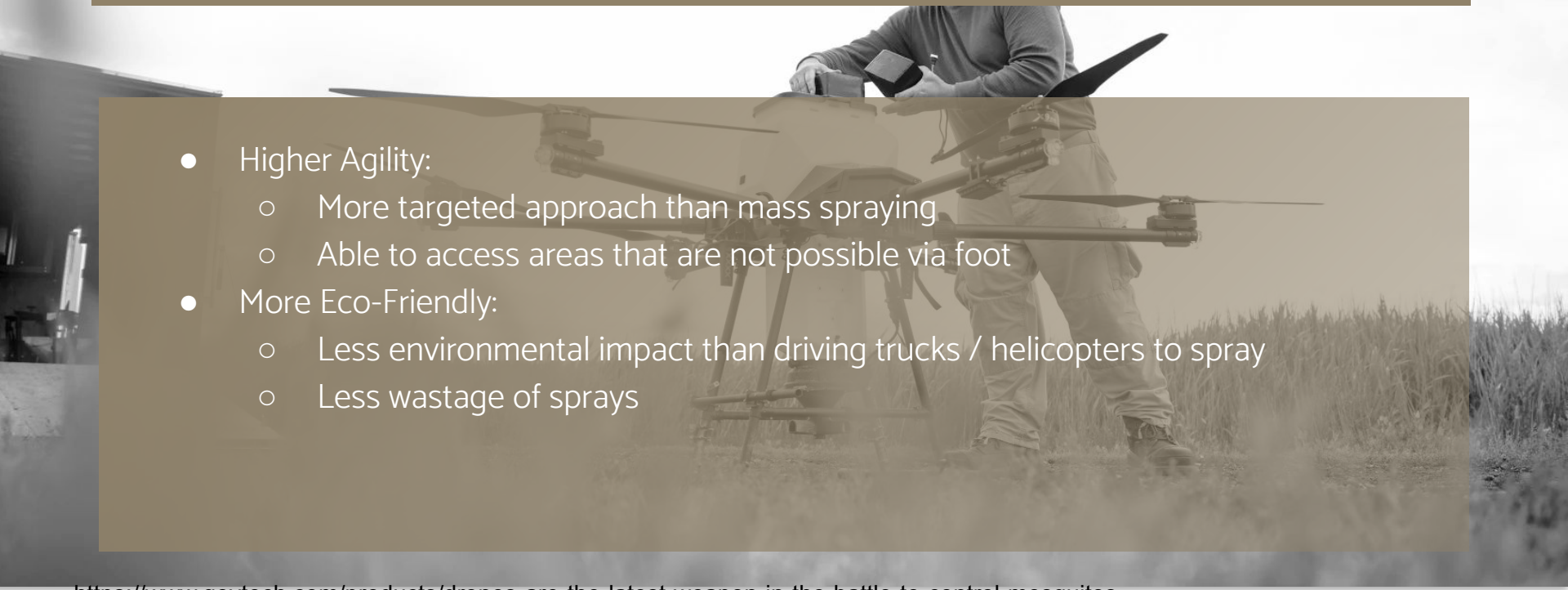
2. MORE DRAMATIC AND IMPACTFUL PUBLIC EDUCATION / CAMPAIGNS

Current posters used in WnV:



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

https://www.govtech.com/products/drones-are-the-latest-weapon-in-the-battle-to-control-mosquitos

Thank You

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.

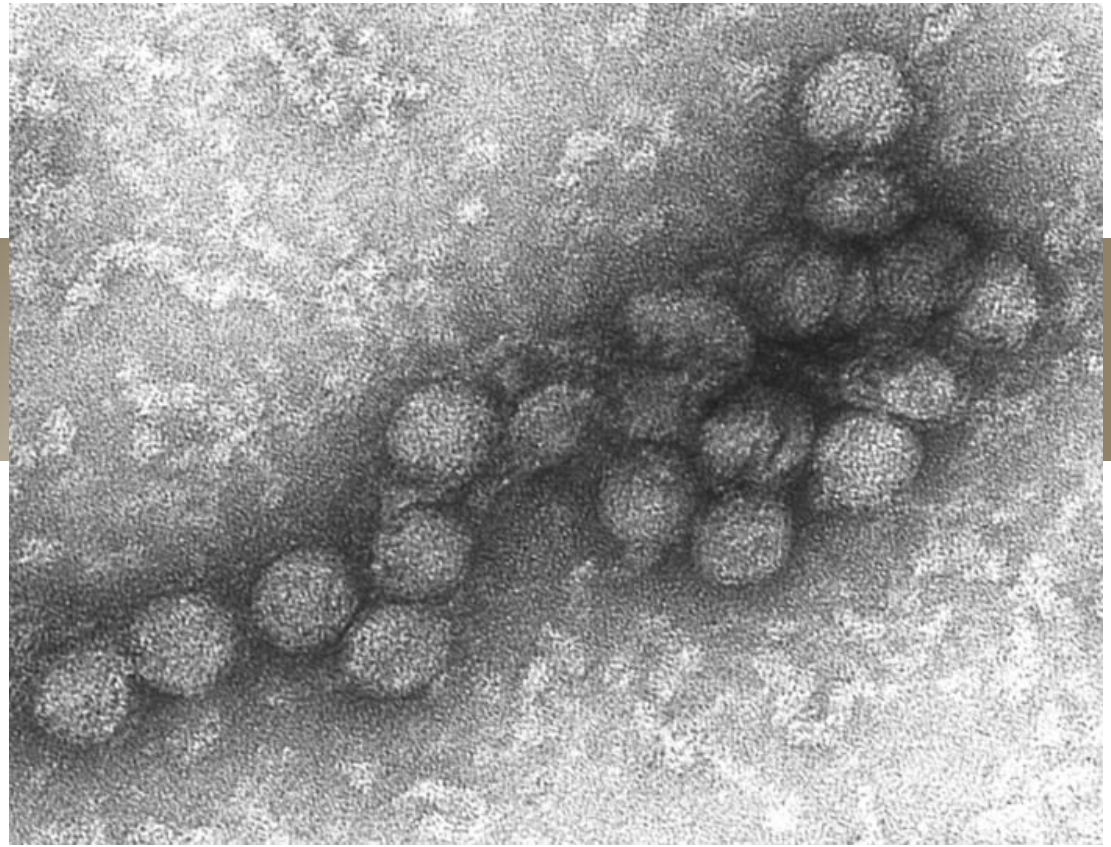
By Cecelia Smith-Schoenwalder | Sept. 18, 2023, at 2:36 p.m.

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

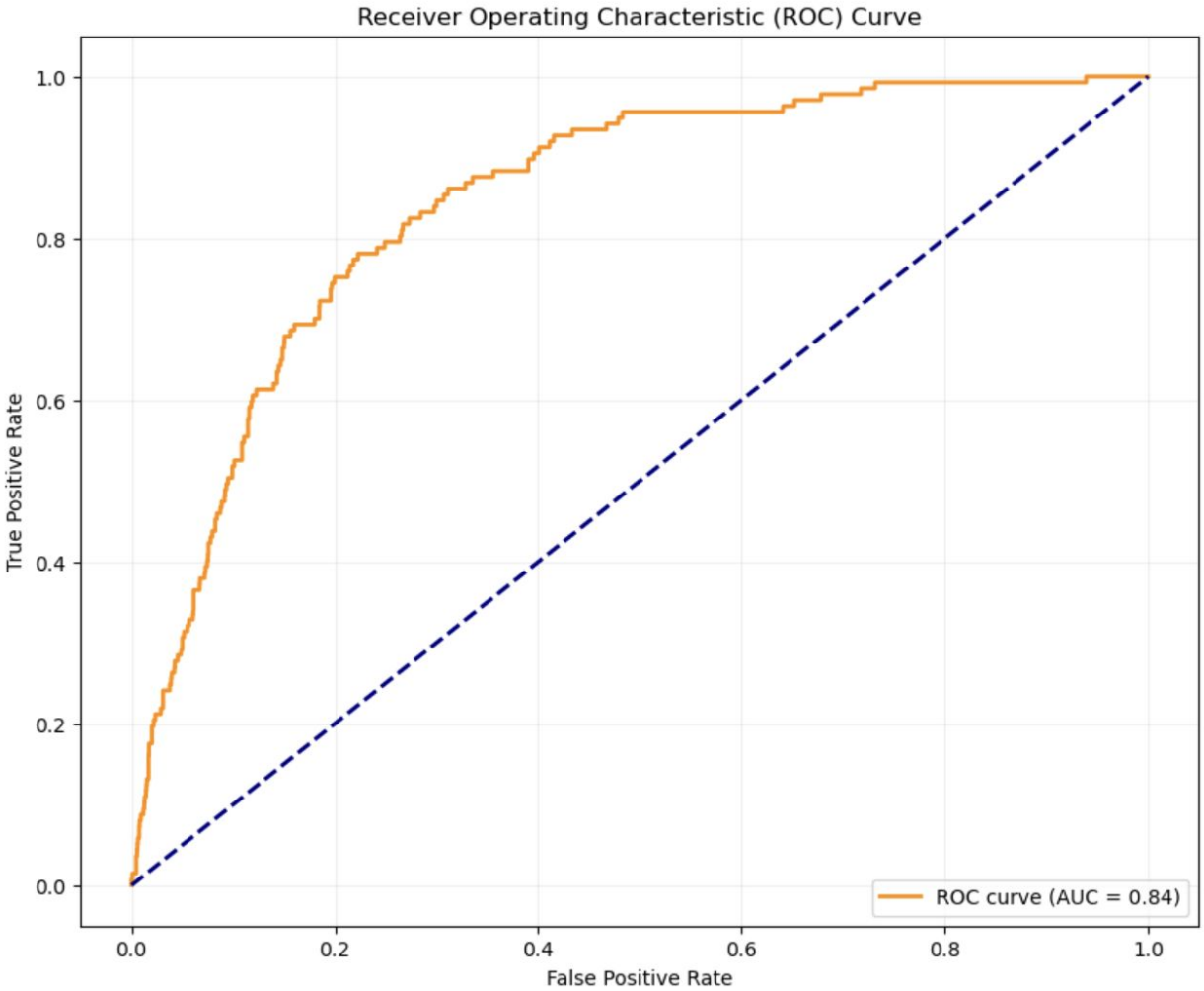


WEST NILE VIRUS

- commonly found in **Africa, Europe, the Middle East, North America and West Asia**
- can cause ***neurological disease*** and ***death*** in people
- transmitted between birds and mosquitoes.
- Can infect humans, horses and other mammals

Source: https://www.who.int/news-room/fact-sheets/detail/west-nile-virus#:~:text=WNV%20is%20commonly%20found%20in,other%20mammals%20can%20be%20infected.

ROC AUC Score



Data: Weather & Spray

Spray Data

Column name	Data type	Description
date	object	Date of spray from 29-08-2011 to 05-09-2013
time	object	Time of spray between 6.56pm to 8.05pm
latitude	float	Latitude returned from Geocoder
longitude	float	

Weather Data (key features)

Column name	Data type	Description
dewpoint	object	Avg dew point in deg F
preciptotal	object	Rainfall and melted snow in inches
tmax	integer	Max temperature in deg F
tmin	integer	Min temperature in deg F
tavg	float	Avg temperature in deg F
wetbulb	object	Avg wet bulb in deg F
heat	object	How much "heating" needed to reach a comfortable baseline of 65°F (SEASON BEGINS WITH JULY)

THANKS

FACTS ABOUT 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

Source(s): https://www.mosquitomagnet.com/articles/when-are-mosquitoes-most-active
https://www.cdc.gov/mosquitoes/about/life-cycles/culex.html