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Article

Mosquito-Borne Diseases in Greece: An Infodemiology Study with Entomological and Citizen-Science Perspectives

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Abstract

Mosquito-borne diseases remain a relevant public health concern in Greece, where surveillance, preparedness, risk communication, and blood safety measures may be affected during periods of increased transmission or imported case detection. This retrospective ecological infodemiology study explored associations between official human mosquito-borne disease data in Greece and digital information-seeking activity during 2024–2025. Official epidemiological data were obtained from the Hellenic National Public Health Organization (EODY). Google Trends Relative Search Volume (RSV) values and Greek-language Wikipedia pageviews were extracted for predefined mosquito-borne disease indicators. Inferential analysis focused on West Nile virus (WNV). In 2024, Greece recorded 220 domestic and 6 imported WNV cases, with 35 deaths. Monthly domestic WNV cases showed significant positive associations with Google Trends RSV for both "ιός του Δυτικού Νείλου" (Spearman rho = 0.694, p = 0.012; Pearson r = 0.920, p < 0.001) and "West Nile virus" (Spearman rho = 0.897, p < 0.001; Pearson r = 0.951, p < 0.001), and with Greek-language Wikipedia pageviews for "ιός του Δυτικού Νείλου" (Spearman rho = 0.758, p = 0.004; Pearson r = 0.917, p < 0.001). Local surveillance data from Crete additionally documented human events, vector presence, winter mosquito activity, and negative molecular testing of examined mosquito samples. Digital attention indicators showed their clearest and most epidemiologically coherent pattern for WNV. These findings support cautious use of digital attention indicators as complementary measures of public attention and situational awareness.

Keywords: infodemiology; infoveillance; Google Trends; Wikipedia; mosquito-borne diseases; West Nile virus; dengue; chikungunya; malaria; entomological surveillance; citizen science

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1. Introduction

Mosquito-borne diseases represent an increasingly important public health challenge, particularly in the Mediterranean basin, where climate change is reshaping vector ecology and transmission potential. Rising temperatures, including unusually warm winter periods, may permit prolonged mosquito survival, continued breeding activity, and earlier seasonal population expansion [1–8]. At the same time, invasive mosquitoes of major public health importance, such as *Aedes aegypti*, pose an additional threat through their potential establishment and spread in climatically suitable Mediterranean areas. These developments have increased concern regarding the changing epidemiology of mosquito-borne diseases and the need for strengthened surveillance, preparedness, and risk communication in the region [9–14].

Beyond the Mediterranean context, mosquito-borne diseases remain an important and evolving global public health challenge, contributing substantially to infectious disease morbidity and requiring sustained surveillance, preparedness, prevention, and risk communication. Their relevance in Europe is shaped not only by ecology and climate, but also by international travel, tourism, cross-border mobility, and arrivals from endemic settings, which may contribute to imported infections and increase the operational importance of surveillance and preparedness. Greece represents a relevant setting for such an investigation because official human surveillance data are available nationally, while mosquito-borne disease preparedness has implications beyond case detection alone, including blood safety interventions during periods of WNV circulation [15–17].

Across Europe, mosquito-borne diseases are becoming an increasingly important public health concern, driven in part by the geographic expansion and re-emergence of key vector species. *Aedes albopictus*, a major vector of dengue, chikungunya, and Zika viruses, has expanded substantially during the past decade, while *Aedes aegypti*, once eliminated from Europe, has re-emerged in Cyprus. At the same time, *Culex pipiens* continues to sustain West Nile virus transmission across large parts of the continent, particularly during summer and early autumn. Recent increases in locally acquired dengue cases, the broad geographic distribution of West Nile virus infections, and the unusually early occurrence of locally acquired chikungunya outbreaks in 2025 collectively suggest that mosquito-borne disease risk in Europe is becoming more geographically widespread, seasonally extended, and operationally important for public health systems [18–23].

At the same time, the digital transformation of society has changed the public health information environment. Traditional surveillance remains essential, but digital traces generated through online search activity may provide complementary insight into population-level attention, information-seeking behaviour, and perceived risk. This has led to growing interest in infodemiology and infoveillance. However, digital attention indicators must be interpreted cautiously, as search intensity and pageviews may reflect media attention, seasonal mosquito nuisance, or public anxiety as much as true epidemiological activity. Google Trends provides normalized Relative Search Volume values rather than absolute search volumes, whereas Wikipedia pageviews provide counts of visits to specific pages and may capture a distinctpathway of disease-related online attention [24–28].

The inclusion of Crete in the present study was not based merely on data availability. Crete represents a Mediterranean island setting of particular public health relevance because it combines climate-sensitive mosquito ecology, intense tourism, seasonal population turnover, and arrivals from endemic regions with structured human, entomological, and laboratory surveillance. In such a setting, even a limited number of human mosquito-borne disease events may have operational importance for preparedness, early detection, vector monitoring, rapid diagnostic vigilance, and risk communication. This relevance is further reinforced by unpublished local winter entomological surveillance data from Crete showing low but detectable mosquito activity during January–March 2024, including the presence of genera of public health importance. Together, these observations support the view that Mediterranean preparedness may increasingly need to account for extended or less clearly bounded mosquito activity under climate-sensitive conditions [29–34].

Against this background, the present study explored associations between digital attention indicators and official human case data for mosquito-borne diseases in Greece during 2024–2025. In addition, descriptive human, entomological, and molecular surveillance findings from Crete were included to contextualize the national analysis within a real Mediterranean island preparedness setting. The specific aims of the study were: (i) to describe official human mosquito-borne disease occurrence in Greece during the study period; (ii) to analyse temporal patterns in Google Trends and Greek-language Wikipedia pageviews for selected mosquito-borne diseases; (iii) to explore associations between digital attention indicators and official human case data, with inferential analysis focused on WNV; and (iv) to contextualize these findings using local human, entomological, molecular, and winter surveillance data from Crete.

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2. Materials and Methods

2.1. Study Design

This was a retrospective ecological infodemiology study that examined associations between official human mosquito-borne disease data in Greece and digital information-seeking activity during 2024–2025. A descriptive local surveillance component from Crete was added to contextualize the national findings.

2.2. Human Epidemiological Data

Official human mosquito-borne disease data were obtained from publicly available surveillance reports and epidemiological documents issued by the Hellenic National Public Health Organization (EODY). The main national analysis focused on WNV, malaria, dengue, chikungunya, and Zika virus disease. Only mosquito-borne diseases were included in the present study. Tick-borne diseases, leishmaniasis, and other non-mosquito vector-borne diseases were excluded.

From the available official data, inferential analysis was feasible primarily for WNV. For WNV, weekly cumulative official EODY reports for 2024 and the annual WNV report were used to reconstruct monthly domestic human case counts for inferential analysis. These monthly domestic counts were derived as follows: January–June 2024, 0 cases; July, 33 cases; August, 91 cases; September, 68 cases; October, 22 cases; November, 4 cases; and December, 2 cases. This reconstruction was based on cumulative weekly totals reported by EODY and was consistent with the annual total of 220 domestic human WNV cases in 2024.

2.3. Digital Search Data

Digital information-seeking data were obtained from two sources, Google Trends and Greek-language Wikipedia pageviews, for the same study period used in the epidemiological analysis, namely from 1 January 2024 to 31 December 2025. Both sources were used as core infodemiology indicators in order to examine temporal patterns of public online attention related to mosquito-borne diseases in Greece.

Google Trends data were extracted for Greece using the Web Search option. Google Trends provides normalized Relative Search Volume (RSV) values ranging from 0 to 100, where 100 reflects the peak popularity of a term within the selected time period and geographical setting. Search terms were selected a priori and were restricted to mosquito-borne diseases only. The main disease-specific terms included Greek and English versions of West Nile virus, malaria, dengue, chikungunya, and Zika, depending on data availability and interpretability.

Greek-language Wikipedia pageview data were extracted for the same period, from 1 January 2024 to 31 December 2025, for the Greek-language disease-specific pages “Ελονοσία”, “Δάγκειος πυρετός”, “Ιός του Δυτικού Νείλου”, “Τσικουνγκούνια”, and “Ιός Ζίκα”. Monthly pageviews were aggregated to match the temporal structure of the epidemiological dataset and the Google Trends dataset.

Thus, for each mosquito-borne disease included in the study, three temporally aligned monthly indicators were assembled: official human case counts, Google Trends RSV, and Greek-language Wikipedia pageviews. These datasets were analysed jointly in order to assess whether digital attention patterns corresponded to official epidemiological activity during the same period.

2.4. Local Surveillance Data from Crete

Descriptive local surveillance data from Crete were supplied by the investigators and included aggregated human mosquito-borne disease events, routine entomological surveillance records, an additional unpublished winter entomological surveillance dataset, and molecular testing results. Local human surveillance data documented 1 imported malaria case in 2024, 2 imported malaria cases in 2025, 1 imported dengue case in 2025, and 1 autochthonous WNV case. The routine

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entomological database covered 2024 and 2025 and included trap-based mosquito collections using Ecodev and Triple Trap systems, with species-level identification results. The unpublished winter surveillance dataset covered January–March 2024 and was based on 16 fixed CO_2-light traps, with emphasis on urban areas, ports, airports, and other entry points. Sampling was conducted every fifteen days, yielding 96 adult mosquito sampling events and 360 collected mosquitoes. Species identification was performed at species level, and meteorological variables were also recorded during trap deployment. Selected mosquito samples from the local surveillance programme underwent molecular testing at IMBB/FORTH for WNV, Usutu virus, chikungunya virus, and Zika virus; all tested samples were negative.

2.5. Statistical Analysis

The statistical analysis examined the temporal relationship between official human mosquito-borne disease occurrence and two digital attention indicators, Google Trends RSV and Greek-language Wikipedia pageviews, during the period from 1 January 2024 to 31 December 2025. All analyses were restricted to mosquito-borne diseases.

Monthly official human case counts were compared with monthly Google Trends RSV values and monthly Wikipedia pageviews for the same diseases and the same observation period. Because epidemiological and digital variables were expected to show non-normal distributions, seasonal concentration, and multiple zero values, Spearman's rank correlation coefficient (rho) was selected as the primary measure of association. Pearson's correlation coefficient (r) was additionally calculated as a secondary parametric measure. Correlation coefficients were interpreted descriptively as weak (<0.30), moderate (0.30–0.69), or strong (≥0.70). Two-sided p-values were reported, and statistical significance was set at $p < 0.05$.

The main pairwise analyses included the following comparisons: official human cases versus Google Trends RSV, official human cases versus Wikipedia pageviews, and Google Trends RSV versus Wikipedia pageviews. Lag analyses were additionally performed to assess temporal relationships between epidemiological activity and digital attention. Associations were examined for the same month (lag 0), for digital indicators preceding reported cases by one month (lag +1), and for digital indicators following reported cases by one month (lag −1).

Simple linear regression models were performed only for diseases with sufficient temporal structure and data availability. Because WNV provided the strongest combination of official human case burden, seasonal structure, and digital signal, it constituted the main inferential focus of the study. However, the same analytical framework was applied descriptively to the other mosquito-borne diseases whenever the available data permitted meaningful comparison. Local data from Crete were analysed descriptively and were not included in the main national inferential models. All analyses were conducted using Epi Info v7.2.7.0 (Centers for Disease Control and Prevention, Atlanta, GA, USA)..

3. Results

3.1. Official Human Mosquito-Borne Disease Data in Greece

According to EODY, 220 domestic human WNV cases were diagnosed and reported in Greece in 2024, including 157 cases with central nervous system manifestations and 63 cases without such manifestations. An additional 6 imported WNV cases were recorded. EODY also reported 35 deaths among hospitalized patients with WNV infection in 2024. The first symptomatic case of the season had symptom onset in epidemiological week 25, and the last diagnosed case of the season was identified in epidemiological week 44, indicating a transmission period extending from June to October 2024. EODY additionally provides geographical information for WNV by estimated municipality of exposure. Table 1 summarizes the official human mosquito-borne disease data used in this study.

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Table 1. Official human mosquito-borne disease data in Greece, 2024–2025.

Disease	Year	Total reported cases	Imported cases	Domestic / autochthonous cases	Deaths	Notes
West Nile virus	2024	226	6	220	35	Transmission period June–October 2024
Malaria	2024	35	35	0	NR	All laboratory-confirmed cases were imported
Malaria	2025*	28	25	2 probable	NR	1 additional case had undetermined place/mode of transmission
Dengue	2024**	4	4	0	NR	3 traveller-associated imported cases plus 1 additional case

*Up to 1 September 2025. **Up to 28 May 2024. NR = not reported in the source used.

For malaria, EODY reported 35 laboratory-confirmed cases in Greece in 2024, all classified as imported. Up to 1 September 2025, 28 laboratory-confirmed malaria cases had been reported, including 25 imported cases, 2 probable domestically acquired cases, and 1 case with undetermined place or mode of transmission. For *Aedes*-borne diseases, the EODY alert document updated on 28 May 2024 reported 3 imported dengue cases in travellers plus 1 additional imported dengue case exposed and diagnosed in Thailand. No corresponding case count was reported in the same document for chikungunya or Zika virus disease up to that update date.

3.2. Inferential Infodemiology Analysis for West Nile Virus

Since WNV provided the most suitable combination of official human case burden, seasonal structure, and digital attention indicators. Monthly domestic human WNV case counts in Greece for 2024 were compared with monthly Google Trends RSV values for the terms “ιός του Δυτικού Νείλου” and “West Nile virus”. Table 2 presents the reconstructed monthly domestic human WNV case counts.

Table 2. Monthly domestic human West Nile virus cases in Greece reconstructed from official EODY surveillance reports, 2024.

Month	Domestic human WNV cases
January	0
February	0
March	0
April	0
May	0
June	0
July	33
August	91
September	68
October	22
November	4
December	2

For the Greek term "ιός του Δυτικού Νείλου", a statistically significant positive association was observed with monthly domestic human WNV case counts (Spearman rho = 0.694, p = 0.012; Pearson r = 0.920, p < 0.001). For the English term "West Nile virus", the association was stronger (Spearman rho = 0.897, p < 0.001; Pearson r = 0.951, p < 0.001). Greek-language Wikipedia pageviews for the page "Ιός του Δυτικού Νείλου" also showed a strong positive association (Spearman rho = 0.758, p = 0.004; Pearson r = 0.917, p < 0.001). Table 3 summarizes the peak digital attention indicators for the selected mosquito-borne diseases, and Table 4 presents the correlation results for WNV.

Table 3. Peak digital attention indicators for selected mosquito-borne diseases, 2024–2025.

Indicator type	Disease / term / page	Language	Peak month	Peak value	Other notable months
Google Trends	"ιός του Δυτικού Νείλου"	Greek	Aug 2024	100	Sep 2024 = 47; Aug 2025 = 71
Google Trends	West Nile virus	English	Jul 2025	100	Aug 2024 = 93; Sep 2024 = 76; Oct 2024 = 54
Google Trends	"δάγκειος πυρετός"	Greek	May 2024	100	Jun 2024 = 32
Google Trends	dengue	English	Dec 2025	100	Jun 2024 = 89; Nov 2025 = 98
Google Trends	chikungunya	English	Aug 2025	100	Sep 2025 = 17; Oct 2025 = 22; Dec 2025 = 29
Wikipedia	"Ελονοσία"	Greek page	Apr 2024	2616	Jan 2024 = 2533; Jan 2025 = 2529; Mar 2024 = 2354
Wikipedia	"Δάγκειος πυρετός"	Greek page	May 2024	4738	Jun 2024 = 2430; Mar 2024 = 2082; Jul 2024 = 1502
Wikipedia	"Ιός του Δυτικού Νείλου"	Greek page	Aug 2024	3435	Aug 2025 = 1473; Sep 2024 = 1071; Sep 2025 = 908
Wikipedia	"Τσικουνγκούνια"	Greek page	Aug 2025	2155	Dec 2025 = 305; Jul 2025 = 229; Sep 2025 = 188
Wikipedia	"Ιός Ζίκα"	Greek page	Mar 2024	295	Jun 2024 = 254; May 2024 = 218; Oct 2024 = 211

Lag analyses showed that the strongest association for both Google Trends terms was observed in the same month, indicating that digital search activity was most closely aligned with same-month official human case occurrence. For "ιός του Δυτικού Νείλου", the correlation remained significant at a lag of 1 month (Spearman rho = 0.632, p = 0.037) when the digital indicator lagged behind reported cases by 1 month (Spearman rho = 0.481, p = 0.134). For "West Nile virus", significant associations were also observed at at a lag of 1 month (Spearman rho = 0.626, p = 0.039) and with the digital indicator trailing by 1 month (Spearman rho = 0.762, p = 0.006), although the strongest signal remained in the same month. For Greek-language Wikipedia pageviews of "Ιός του Δυτικού Νείλου", the strongest association was observed at a lag of 1 month (Spearman rho = 0.820, p = 0.002), while the reverse 1-month lag association was not statistically significant (Spearman rho = 0.580, p = 0.061). Table 4 presents the correlation results.

Table 4. Correlation between monthly domestic human West Nile virus cases and digital attention indicators in Greece, 2024.

Digital indicator	Correlation type	Lag	Coefficient	p-value	Interpretation

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"ιός του Δυτικού Νείλου" (Google Trends)	Spearman	0	0.694	0.012	Significant positive association
"ιός του Δυτικού Νείλου" (Google Trends)	Pearson	0	0.920	<0.001	Strong positive linear association
"ιός του Δυτικού Νείλου" (Google Trends)	Spearman	+1 month	0.632	0.037	Significant lagged association
"ιός του Δυτικού Νείλου" (Google Trends)	Spearman	−1 month	0.481	0.134	Not statistically significant
West Nile virus (Google Trends)	Spearman	0	0.897	<0.001	Very strong positive association
West Nile virus (Google Trends)	Pearson	0	0.951	<0.001	Very strong positive linear association
West Nile virus (Google Trends)	Spearman	+1 month	0.626	0.039	Significant lagged association
West Nile virus (Google Trends)	Spearman	−1 month	0.762	0.006	Significant lagged association
"Ιός του Δυτικού Νείλου" (Wikipedia)	Spearman	0	0.758	0.004	Strong positive association
"Ιός του Δυτικού Νείλου" (Wikipedia)	Pearson	0	0.917	<0.001	Strong positive linear association
"Ιός του Δυτικού Νείλου" (Wikipedia)	Spearman	+1 month	0.820	0.002	Significant lagged association
"Ιός του Δυτικού Νείλου" (Wikipedia)	Spearman	−1 month	0.580	0.061	Not statistically significant

3.3. Descriptive Temporal Comparison Between Epidemiological Activity and Digital Indicators

Digital attention indicators showed distinct patterns across the selected mosquito-borne diseases. For "δάγκειος πυρετός", Google Trends activity was minimal, with only two non-zero months in 2024. By contrast, "dengue" showed a broader and more persistent Google Trends pattern, and Greek-language Wikipedia pageviews showed marked spikes for "Δάγκειος πυρετός" in May 2024 and for "Τσικουνγκούνια" in August 2025. Overall, WNV-related digital activity showed the clearest temporal concentration and the closest descriptive alignment with official transmission in Greece. Monthly Greek-language Wikipedia pageviews for the selected mosquito-borne diseases during 2024–2025 are shown in Figure 1. The figure illustrates marked differences in digital attention across diseases and over time, with clearer temporal concentration for some diseases than for others.

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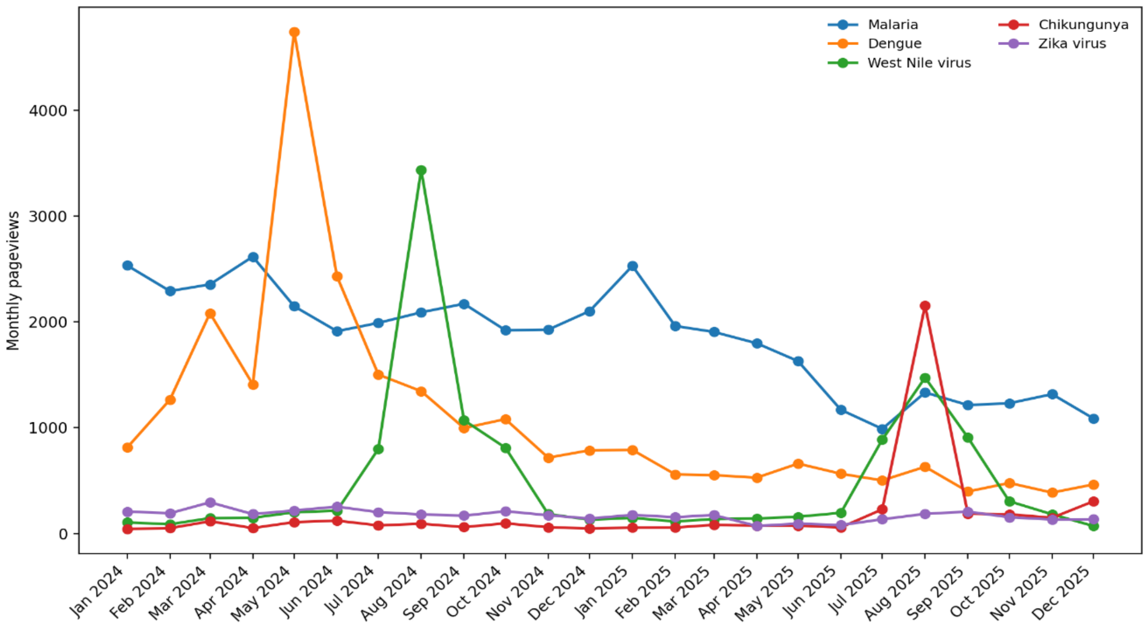

Figure 1. Monthly pageviews for selected Greek-language Wikipedia pages related to mosquito-borne diseases, 2024–2025. The figure shows monthly pageviews for the Greek-language Wikipedia pages "Ελονοσία", "Δάγκειος πυρετός", "Ιός του Δυτικού Νείλου", "Τσικουνγκούνια", and "Ιός Ζίκα" during the study period.

Table 5. Descriptive temporal comparison between official epidemiological activity and digital indicators in Greece, 2024–2025.

Disease / indicator set	Official epidemiological pattern	Digital pattern	Descriptive interpretation
West Nile virus	Official transmission period June–October 2024	Google Trends and Greek-language Wikipedia both peaked in late summer 2024	Strongest temporal concordance
Dengue	Few imported cases officially reported	Google Trends and Greek-language Wikipedia showed broader multi-month attention	Likely influenced by wider information environment
Chikungunya	Sparse official human data	Digital attention rose mainly in 2025, especially in Wikipedia	Weak anchoring to national human case burden
Malaria	Imported human cases with limited seasonality	Greek-language Wikipedia pageviews remained comparatively stable	Low temporal specificity
Zika	Sparse or absent official signal	Low and relatively flat Greek-language Wikipedia pattern	Minimal digital attention signal

3.4. Local Surveillance Context from Crete

According to local surveillance data provided by the investigators, Crete recorded 1 imported malaria case in 2024, 2 imported malaria cases in 2025, 1 imported dengue case in 2025, and 1 autochthonous WNV case. These local events occurred within a Mediterranean island setting characterized by seasonal tourism, population mobility, and climate-sensitive mosquito ecology, and therefore have practical relevance for preparedness, diagnostic vigilance, and risk communication even when case counts are low.

The routine entomological surveillance database from Crete included 672 species-level records in 2024 and 596 in 2025. In 2024, the trap dataset comprised 583 Ecodev records and 90 Triple Trap records, while in 2025 it comprised 497 Ecodev records and 99 Triple Trap records. *Culex* pipiens was the dominant mosquito species in both years, followed by species including *Aedes* albopictus, *Aedes* caspius, *Culex* perexiguus, and *Anopheles* claviger, depending on year. Molecular testing performed at the Molecular Entomology Laboratory (IMBB/FORTH) on selected mosquito samples was negative for West Nile virus, Usutu virus, chikungunya virus, and Zika virus during the study period. Table 6 summarizes the local surveillance context from Crete, and Table 7 presents the leading female mosquito species identified in the routine surveillance dataset.

Additional unpublished winter entomological surveillance conducted in Crete during January–March 2024 further supported the local preparedness relevance of the island setting. In that winter survey, 16 fixed CO_2-light traps were deployed with emphasis on urban areas and points of entry (ports and airports), yielding 360 mosquitoes across 96 adult mosquito sampling events. Five genera were identified, predominantly *Culex* (96.5%), with smaller numbers of *Aedes*, *Ochlerotatus*, *Anopheles*, and *Culiseta*. The mean number of mosquitoes collected per sampling event was below 3, and no pathogens were detected in the examined samples. These findings suggest that mosquito presence in Crete may persist at low but detectable levels during winter months under local conditions. Table 8 summarizes the unpublished winter entomological surveillance findings.

To further contextualize vector activity during 2025, descriptive indicators from the fixed regional surveillance networks were examined for the three genera most relevant to local mosquito-borne disease preparedness (*Culex*, *Aedes*, and *Anopheles*). Weekly positivity rates of breeding-site samples for larvae are presented for *Culex* (Figure 2A), *Aedes* (Figure 2B), and *Anopheles* (Figure 2C), with 2025 values compared to historical averages for the same fixed network. In addition, mean adult female captures per 15-day period are presented for *Culex* (Figure 2D), *Aedes* (Figure 2E), and *Anopheles* (Figure 2F), with 2025 values compared to historical averages for the same fixed network. Taken together, these indicators suggest detectable larval and adult mosquito activity in 2025 relative to historical baselines. These figures were included as descriptive local surveillance findings to support interpretation of preparedness and vector presence and were not used in the main inferential analysis.

Table 6. Local surveillance context from Crete.

Component	2024	2025
Imported malaria cases (local surveillance data)	1	2
Imported dengue cases (local surveillance data)	0	1
Autochthonous WNV cases (local surveillance data)	1	0
Entomological species-level records	672	596
Ecodev trap records	583	497
Triple Trap records	90	99
Dominant mosquito species	*Culex pipiens*	*Culex pipiens*
Molecular detection of WNV, Usutu, chikungunya, Zika	Not detected	Not detected

Table 7. Leading female mosquito species identified in Crete routine surveillance.

Year	Species	Female count
2024	*Culex pipiens*	1586
2024	*Aedes caspius*	118
2024	*Aedes albopictus*	68
2024	*Culex perexiguus*	61
2025	*Culex pipiens*	1359

2025	*Culex perexiguus*	169
2025	*Aedes albopictus*	118
2025	*Anopheles claviger*	38

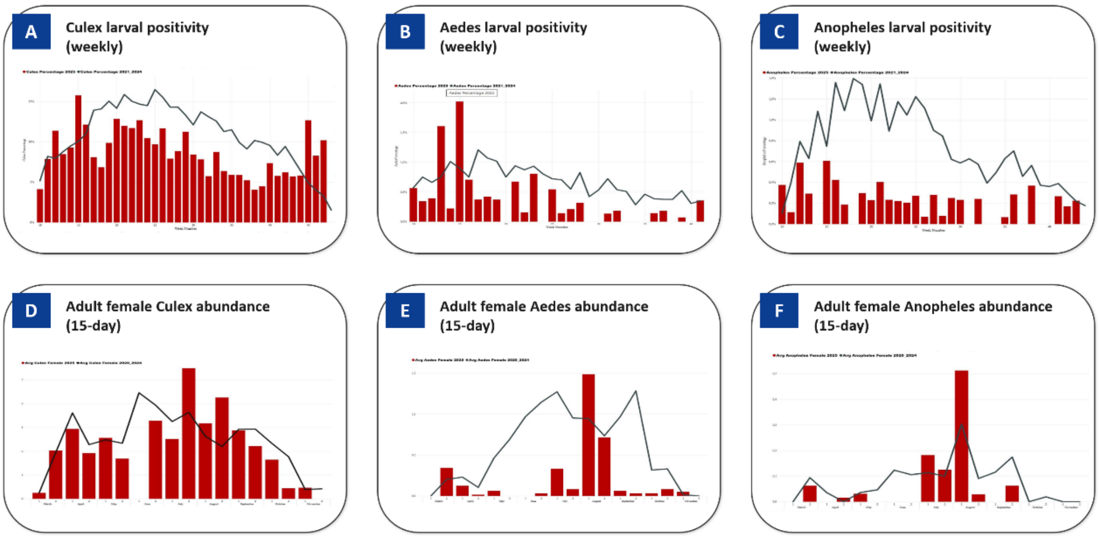

Figure 2. Descriptive local surveillance indicators of larval positivity and adult mosquito abundance for Culex, Aedes, and Anopheles in Crete, 2025, compared with historical averages. Panel A shows the weekly positivity rate of breeding-site samples for *Culex* larvae. Panel B shows the weekly positivity rate of breeding-site samples for *Aedes* larvae. Panel C shows the weekly positivity rate of breeding-site samples for *Anopheles* larvae. Panel D shows the mean adult female *Culex* captures per 15-day period. Panel E shows the mean adult female *Aedes* captures per 15-day period. Panel F shows the mean adult female *Anopheles* captures per 15-day period. In all panels, the red bars represent 2025 values and the black line represents the historical mean for the same surveillance network. These indicators were included as descriptive local surveillance findings and were not used in the main inferential analysis.

Table 8. Summary of unpublished winter entomological surveillance findings in Crete, January–March 2024.

Parameter	Finding
Fixed traps	16 CO_2-light traps
Sampling period	January–March 2024
Sampling frequency	Every 15 days
Total adult mosquito sampling events	96
Total mosquitoes collected	360
Mean mosquitoes per sampling event	<3
Main identified genera	*Culex*, *Aedes*, *Ochlerotatus*, *Anopheles*, *Culiseta*
Genus distribution	*Culex* 96.5%; *Aedes* 0.5%; *Ochlerotatus* 1%; *Anopheles* 1%; *Culiseta* 2%
Pathogen detection	None detected
Interpretation	Low but detectable winter mosquito activity

4. Discussion

This study combined official national human surveillance data, Google Trends search activity, Greek-language Wikipedia pageviews, and local contextual surveillance findings to explore the infodemiology and infoveillance of mosquito-borne diseases in Greece. The clearest digital signal emerged for West Nile virus (WNV), for which online attention showed marked late-summer concentration and statistically significant positive associations with monthly official domestic human case counts. The strongest Google Trends associations were observed at lag 0, whereas Greek-language Wikipedia pageviews showed their strongest association at lag +1 month, suggesting that disease-specific pageviews may in some instances persist slightly longer after epidemiological activity has intensified [35–37].

Our findings are broadly consistent with previous Italian work on arboviral infodemiology and infoveillance. In particular, Santangelo et al. reported significant correlations between official surveillance data and digital indicators, including Google Trends and Wikipedia, across the most widespread arboviral diseases in Italy, although the strength of association varied by pathogen. Similarly, Provenzano et al. showed that Wikipedia-based information-seeking activity may correlate with conventional arboviral surveillance data, supporting the use of pageview patterns as complementary indicators of public attention. In this context, the present Greek findings reinforce the view that digital indicators can meaningfully reflect mosquito-borne disease dynamics, but that their performance is pathogen-specific rather than uniform across all arboviruses [38].

The stronger performance of WNV in the present study is epidemiologically plausible. In Greece, WNV has a clear seasonal profile, recurrent public-health salience, and operational implications that extend beyond case notification alone. During transmission periods, WNV is linked to enhanced risk communication, mosquito-control awareness, and blood safety measures, including nucleic acid testing and donor-management procedures in affected areas. These characteristics likely amplify both immediate search activity and more sustained information-seeking behaviour, making WNV particularly suitable for infodemiology and infoveillance analyses. By contrast, dengue and chikungunya in Greece currently remain much more dependent on imported-case patterns or low domestic activity, meaning that digital attention may be shaped more strongly by international media coverage, travel concerns, and global outbreak narratives than by the national epidemiological situation itself. This interpretation is also compatible with the Italian experience, where arboviral digital signals were heterogeneous rather than identical across pathogens [39].

The contrast between Greek-language and English-language Google Trends patterns was also notable. The English term “West Nile virus” showed stronger same-month and lagged correlations than the Greek term “ιός του Δυτικού Νείλου”, while Greek-language Wikipedia pageviews for “Ιός του Δυτικού Νείλου” still showed a positive relationship with monthly domestic WNV cases, albeit with the strongest monotonic association at lag +1 month rather than lag 0. This suggests that different digital platforms may capture partly overlapping but not identical dimensions of public attention. Search queries may reflect rapid, event-driven information-seeking responses, whereas Wikipedia pageviews may capture more deliberate, confirmatory, or sustained consultation behaviour. This interpretation is in line with the broader methodological literature, which emphasizes that Google Trends and Wikipedia measure related but distinct forms of online behaviour and therefore require careful interpretation rather than direct equivalence [40–45].

The present study also adds a Mediterranean field-preparedness perspective through the inclusion of Crete. Crete was not included merely because local data were available, but because it provided a real local setting in which human mosquito-borne disease events, vector surveillance, molecular testing, and field monitoring could be considered together. This was especially relevant in light of local imported malaria and dengue cases, the recorded local WNV event, and the documented presence of vector species of public-health importance. The relevance of this setting is further amplified by Mediterranean climatic conditions, climate-related environmental pressures, intense tourism, seasonal mobility, and arrivals from endemic regions. In such contexts, targeted epidemiological vigilance, rapid diagnostic testing, vector monitoring, and local preparedness remain important even when case numbers are low.

Although mosquito densities remained low and no pathogens were detected, the documented presence of *Culex*, *Aedes*, and *Anopheles* genera during January–March 2024 suggests that mosquito activity in Mediterranean island settings may not be strictly confined to the conventional seasonal

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window. These observations support the argument that climate-sensitive preparedness may increasingly need to account for extended or less clearly bounded mosquito activity, especially in areas characterized by warm winters, tourism-related mobility, and persistent citizen complaints of nuisance. The additional local surveillance indicators presented in Figure 2A–F are consistent with the interpretation that mosquito activity in Crete during 2025 was sustained and, in certain instances, initiated earlier in the season relative to historical averages. In addition, the "Kounoupia Watch" initiative in Crete, recently launched within the European DxHub – Excellence Hub project under Horizon Europe WIDERA (Project No. 101186531), provides a timely example of how citizen-science approaches may complement conventional mosquito surveillance. By inviting members of the public to submit geolocated mosquito observations through iNaturalist, with subsequent expert-supported validation and open mapping of records, the initiative creates a participatory framework that can strengthen community engagement and public awareness while also contributing useful field-level contextual information. Such approaches may support the observation not only of mosquito species of public health importance, but also of non-vector taxa, thereby encouraging a more balanced interpretation of entomological risk alongside biodiversity considerations. Although citizen-generated observations cannot replace structured entomological, epidemiological, or laboratory surveillance, they may offer an additional layer of situational awareness when interpreted in conjunction with official public health systems.

At the same time, the findings from Crete highlight an important principle of surveillance interpretation: the documented presence of competent vectors, and even the occurrence of human cases, does not necessarily correspond to molecular positivity in the mosquito samples tested. Negative molecular findings in field-collected mosquitoes may reflect limitations related to sampling scope, temporal alignment, low pathogen prevalence, or the focal nature of arboviral transmission, rather than an absence of epidemiological significance. This consideration is particularly important in the interpretation of local preparedness data, as entomological detection, human case occurrence, and molecular confirmation may not coincide either temporally or spatially.

This study has several limitations. First, Google Trends provides normalized rather than absolute search volumes, which may complicate cross-term interpretation. Second, Greek-language Wikipedia pageviews reflect visits to specific pages and may capture a somewhat different segment of disease-related online attention than search queries. Third, the official source documents varied in temporal detail across diseases, limiting uniform inferential analysis. Fourth, dengue and chikungunya digital signals may have been disproportionately influenced by external information environments. Fifth, the local Cretan human data were used descriptively and not as the basis for national correlation modelling. Finally, the winter entomological dataset from Crete was unpublished and was incorporated as contextual local evidence rather than as part of the primary inferential framework. These limitations are consistent with the broader literature on internet-based disease surveillance, which stresses that digital data can complement but should not replace conventional surveillance systems.

Despite these limitations, the study shows that infodemiology and infoveillance can add value when interpreted cautiously and anchored to official surveillance. In Greece, WNV appears to be the strongest current example of a mosquito-borne disease for which digital behaviors and official epidemiological activity show meaningful temporal convergence. More broadly, comparison with the Italian literature suggests that arboviral digital surveillance in Mediterranean settings may be particularly informative when the pathogen has clear seasonality, recognizable public-health salience, and sufficient epidemiological burden to generate detectable online attention.

5. Conclusions

In Greece during 2024–2025, digital attention related to mosquito-borne diseases was heterogeneous across diseases and platforms. The clearest and most epidemiologically coherent signal was observed for WNV, for which both Google Trends activity and Greek-language Wikipedia pageviews aligned with the official transmission season and monthly domestic human case burden reported by NPHO. Dengue and chikungunya digital patterns were broader and less clearly linked to domestic human case occurrence.

These findings suggest that digital indicators, including Google Trends and Greek-language Wikipedia pageviews, may serve as complementary measures of public attention and situational awareness, especially for seasonally structured mosquito-borne threats such as WNV, but they should not be interpreted as substitutes for official surveillance. The descriptive local surveillance findings from Crete further highlight the importance of integrating human case awareness, vector monitoring, laboratory preparedness, and climate- and mobility-sensitive vigilance in Mediterranean settings. In this context, citizen-science initiatives such as the DxHub "Kounoupia Watch" action in Crete may offer a useful complementary example of participatory awareness and observation, alongside—not instead of—formal surveillance systems.

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Abbreviations

The following abbreviations are used in this manuscript:

EODY	Hellenic National Public Health Organization
RSV	Relative Search Volume
WNV	West Nile virus
IMBB	Institute of Molecular Biology and Biotechnology
FORTH	Foundation for Research and Technology—Hellas
CO_2	Carbon dioxide

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