West Nile virus and drought

West Nile virus was first reported in Uganda in 1937. WNV is a zoonosis, with "spill-over" to humans, which also poses significant risks for wildlife, zoo and domestic animal populations. While it is not known how West Nile virus (WNV) entered the New World in 1999, anomalous weather conditions may have helped amplify this Flavivirus that circulates among urban mosquitoes, birds and mammals. We analyzed weather patterns coincident with a series of U.S. urban outbreaks of St. Louis encephalitis (SLE), (a disease with a similar life cycle), and four recent large outbreaks of WNV. Drought emerged as a common feature. As the potential risks from pesticides for disease control must be weighed against the health risks of the disease, an early warning system of conditions conducive to amplification of the enzootic cycle could help initiate timely preventive measures, and potentially limit chemical interventions.

P. R. Epstein[A Corresponding author] and C. Defilippo[B]

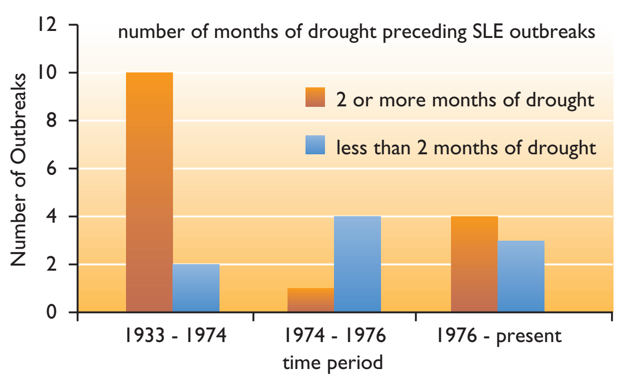
A Center for Health and the Global Environment
Harvard Medical School, USA
fax 617 43 22 595
e-mail paul_epstein@hms.harvard.edu

B Division of Environmental Sciences and Public Policy
Faculty of Arts and Sciences, Harvard University, USA

The means by which WNV entered the Americas remains a mystery; (via imported or migratory birds is plausible[1]). Anomalous weather conditions may have aided its amplification. The first U.S. outbreak of a *Flavivirus* with a similar life cycle -- St. Louis encephalitis (SLE) -- occurred in St. Louis, Missouri in 1933 during the "dust bowl era", following several consecutive years of drought. Subsequent outbreaks have been associated anecdotally with drought.[2] While there are some differences in the life cycles of SLE and WNV, both -- in urban environments -- involve *Culex pipiens* (and probably *C. quinquefasciatus, salinarius* and *restuans*) mosquitoes, birds and mammals.[3] In rural settings, SLE vectors include *C. tarsalis* and *C. nigripalpus*, whose ecology differs from the urban dwelling *C. pipiens*.

C. pipiens thrives in city storm drains and catch basins, especially in the organically rich water that forms during drought.[2,3] Warm temperatures accompanying droughts would also shorten the mosquito extrinsic incubation period of virus, though extreme heat reduces longevity.

We analyzed data on weather (National Climatic Data Center, National Oceanographic and Atmospheric Administration, U.S. Dept of Commerce, www.ncdc.noaa.gov) during 24 U.S. SLE outbreaks. SLE is an appropriate surrogate for study because of its similarity to WNV, and because of the significant number of SLE outbreaks in the U.S. along with accurate weather data. We excluded rural outbreaks and those in Florida and California, as they usually involved *C. negripaplus* and *C. tarsalis*, respectively. We then reviewed precipitation data from the literature for the four major urban WNV outbreaks of the past decade. For the U.S., we used the Palmer Severity Drought Index (PSDI); a meas-



ure of dryness that is a function of precipitation and soil moisture compared with 30 years of data in the same location. The PSDI ranges from –4 (dry) to +4 (wet).

Findings: The first explosive outbreak of SLE occurred in 1933 (1,315 cases, case rate 36/100 000, with *C. pipiens* and *C. quinquefasciatus* involved). Subsequent urban outbreaks between 1933 and 1974 were regionally clustered in Kentucky, Colorado, Texas, Indiana, Tennessee and Illinois. Ten of the twelve urban outbreaks during these first four decades were associated with two or more months of consecutive drought (see graph). (One of the two "unassociated" events followed a one-month drought.)

Note: Outbreaks of SLE, during the 1974-76 period and after, show a variable pattern in relation to weather (occurring with drought or, alternatively, after anomalous rains). Once established in a region, summer rains may boost populations of *Aedes japonicus* and other *Aedes spp.* that can function as "bridge vectors," efficiently carrying virus from birds to humans. The roles of "maintenance" (primarily bird-biting mosquitoes) and bridge vectors in WNV transmission are under study.

Recent episodes of WNV

A significant European outbreak of WNV occurred in 1996 in Romania, in the Danube Valley and in Bucharest. This episode, with hundreds experiencing neurological disease and 17 fatalities, occurred between July and October and coincided with a prolonged drought (May through October) and excessive heat (May through July).[4] Human cases in Bucharest were concentrated in blockhouses situated over an aging sewage system where *C. pipiens* were breeding in abundance.

The 1999 WNV outbreak in New York City followed an extended severe spring and summer drought along the U.S. Atlantic Coast. In July, a three-week heat wave enveloped NYC, with temperatures 4.6°C (~9°F) above the 30-year average. Avian deaths from WNV began in July, and human cases appeared in August. Fifty-nine people developed meningoencephalitis, 7 died[5] and many of the 42 survivors followed-up suffered sequelae (M. Layton, NYC Health Dept., 10/01). (The Atlantic Coast drought ended with torrential rains in NYC on August 26 and Hurricane Floyd centered in North Carolina in September.)

A third large outbreak of WNV occurred in Russia in the summer of 1999, following a drought. Hospitals in the Volgograd Region admitted 826 patients; 84 with meningoencephalitis, of which 40 died.[6]

WNV was first reported in Israel in 1951, and sporadic outbreaks followed.[7] Israel, a major stopover for migrating birds, usually receives little precipitation from May to October. In 2000, the region was especially dry, as drought conditions prevailed across southern Europe and the Middle East, from Spain to Afghanistan. Between August 1 and October 31, 2000, 417 cases of serologically confirmed WNV were diagnosed in Israel with 35 deaths (www.icdc-wnf.co.il). *C. pipiens* was identified as a vector.

Conclusions and discussion

Multi-month drought, especially in spring and early summer, was found to be associated with urban SLE outbreaks from its initial appearance in 1933 through 1973 and with recent severe urban outbreaks of WNV in Europe and the U.S. Other factors, such as inadequate sanitation, sluggish urban waterways and abandoned tires, may increase vulnerability to urban arbovirus outbreaks. Each new outbreak requires introduction or reintroduction of the virus -- primarily via birds or wildlife – so there have been seasons without SLE outbreaks despite multi-month drought. Spread of WNV and sporadic cases may occur, even in the absence of conditions amplifying the enzootic cycling. In Bayesian parlance, drought increases the "prior probability" of a significant outbreak Once the virus becomes established in a region, other factors, such as rains that increase populations of bridge vectors, may affect transmission dynamics.

Further investigation and modeling are needed to determine the role of meteorological factors, and identify reservoirs, overwintering patterns, and the susceptibility of different species associated with WNV. The migration path of many eastern U.S. birds extends from Canada across the Gulf of Mexico to South America (see (http://www.npwrc.usgs.gov/resource/othrdata/migratio/prince.htm). As birds may transfer the virus to new regions, as they become more tolerant carriers, projections of drought for specific regions and urban centers in the U.S. and other nations along the avian flyways could be used to alert communities to the increased risk for significant outbreaks.

Public health implications

These preliminary findings may have important implications for projecting significant outbreaks in virus-naïve regions in the U.S., Canada, the Caribbean, Central and South America and in Europe. Community-based public health measures can include: active (live bird) and passive (dead bird) avian surveillance for WNV, widespread efforts to limit breeding sources, public education and larviciding. Such measures could minimize or obviate the use of adulticides in some communities. L-17rm measures include maintaining the flow of rivers and streams through urban areas to support fish populations that consume mosquito larvae.

References

[1] Rappole JH, Derrickson SR, Hubálek Z. Migratory birds and spread of West Nile virus in the Western Hemisphere. *EID* 2000; 6:319-328.

[2] Monath TP, Tsai TF. St Louis encephalitis: lessons from the last decade. *Am J Trop Med Hyg* 1987; 37:40s-59s.

[3] Spielman A. Population structure in the *Culex pipiens* complex of mosquitoes. *Bull WHO* 1967; 37: 271-276.

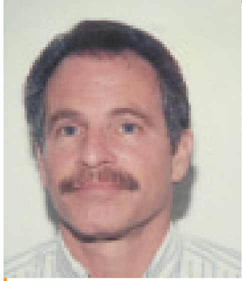
[4] Savage HM, Ceianu G, Nicolescu G, *et al*. [Karabatsos N, Lanciotti R, Vladimirescu A, Laiv A, Ungureanu A, Romanca C, Tsai TF.] Entomologic and avian investigations of an epidemic of West Nile fever in Romania in 1996, with serologic and molecular characterization of a virus isolate from mosquitoes. *Am J Trop Med Hyg* 1999; 61: 600-611.

[5] Nash D, Mostashari F, Fine A, *et al.* [Miller J, O'Leary D, Murray K, Huang A, Rosenberg A, Greenberg A, Sherman M, Wong S, Layton M; 1999 West Nile Outbreak Response Working Group.] The outbreak of West Nile virus infection in the New York City area in 1999. *N Engl J Med* 2001 344:1858-9.

[6] Platonov AE, Shipulin GA, Shipulina OY, *et al*. [Tyutyunnik EN, Frolochkina TI, Lanciotti RS, Yazyshina S, Platonova OV, Obukhov IL Zhukov AN, Vengerov YY, Pokrovskii VI.] Outbreak of West Nile Virus infection, Volgograd region, Russia, 1999. *EID* 2001; 7:128-132.

[7] Marberg K, Goldblum N, Sterk VV, *et al*. The natural history of West Nile fever. I. Clinical observations during an epidemic in Israel. *Am J Hyg* 1956; 64:259-265.

The authors



Paul R. Epstein, M.D., M.P.H. *is Associate Director of the Center for Health and the Global Environment, Harvard Medical School (http://www.med.harvard.edu/chge). Paul is a medical doctor trained in tropical public health, and has worked in medical, teaching and research capacities in Africa, Asia and Latin America. In 1993 he coordinated an eight-part series on Health and Climate Change for the British medical journal, Lancet, and has worked with the Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report, the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA) to assess the health impacts of climate change and develop health applications of climate forecasting and remote sensing.*

Caroline DeFilippo *graduated with honors from Harvard University in June 2001 with a degree in environmental science and public policy. Currently, she is pursuing a graudate diploma in environmental studies at the University of Adelaide, Australia on a Rotary Ambassadorial Scholarship. She plans to pursue a career in public health with a focus on environmental epidemiology.*