COMMENTARY

Comprehensive Surveillance, Prevention, and Control Measures for West Nile Virus in Monroe County, Pennsylvania

Jacquelyn A. Hakim, Adenike C. Bitto

Despite ongoing recession-induced cutbacks of public health program funding, this article presents a feasible option to certain issues raised at the Second National Planning Meeting for the Surveillance, Prevention, and Control of West Nile Virus in the United States (Nasci, 2001; Roehrig, 2001). This county-level, cost-effective program illustrates the importance of maintaining and improving public health infrastructure, including the role of enhanced surveillance and vector control efforts in preventing human cases of infection. Many agencies at the federal, state, and local levels are available to assist in the planning and start-up of such programs. The goal of Monroe County's Vector Control Program has been to minimize or eliminate risk of arthropod-borne disease to residents/resort area visitors, through a comprehensive Integrated Pest Management framework for mosquito surveillance and control. Monroe County has supplemented their efforts with (1) new technology like Internet/Web-based surveillance data reporting, Global Positioning Systems (GPS), and Geographic Information Systems (GIS); (2) vigorous public education and involvement, including mosquito breeding site identification, control strategies for the homeowner/other residents, and use of personal protection measures; (3) active interaction with East Stroudsburg University; and (4) interagency collaboration, including local, state, and federal agencies. Until September 2003, when the first and only (to date) human case was reported, there were no human infection cases in Monroe County.

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Decades of complacency and depletion of financial resources in the Environmental Public Health field known as Vector Control became painfully apparent in 1999, when New York City battled the first epidemic of West Nile Virus in the Western Hemisphere. Furthermore, "... support for arthropod-borne disease surveillance programs is frequently a very low priority in state health departments, and interest and capability regarding these arboviruses have lessened over the past 20–30 years" (Gubler et al., 2001).

At the same time, West Nile Virus now appears to be well established in North America, with competent vectors and reservoir animals. Public health and environmental professionals must recognize the recent nationwide spread of this infectious disease, and acknowledge the need for West Nile Virus prevention and control. Susceptible subgroups of the general population include the elderly, the very young, and immuno-compromised individuals.

This article is addressed to environmental specialists and others involved in developing and maintaining community public health programs. The main goal here is to share a commentary on the structure and components of a model, successful, county-level, comprehensive Integrated Pest Management (IPM) program for vector surveillance and control of West Nile Virus. Subsequent sections of this article provide a description of the West Nile Virus Surveillance Program that was implemented to supplement vector management programs already in place in Monroe County. It is important to note that many agencies at the federal, state, and local levels are available to assist in the planning and start-up of such programs. In addition, this article highlights a public health education component that includes mosquito breeding site identification and control strategies for senior citizens, homeowners and other residents, municipalities, businesses,

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wastewater treatment plant operators, recreational facilities, health agencies, and local news media outlets.

Background

West Nile Virus is a neurotropic virus of the complex known as flaviviruses (genus *Flavivirus*, family Flaviviridae), and was first isolated in 1937 from the blood of a Ugandan woman in a sleeping sickness survey, following a febrile illness (Smithburn et al., 1940). Since then, it has been isolated from birds, mosquitoes, and mammals (Hurlbut, 1956). West Nile Virus causes sporadic outbreaks of disease throughout parts of the Old World, including Africa, Europe, the Middle East, and as far to the east as Thailand (Hubalek and Halouzka, 1999).

Until recently, the outbreaks in the Eastern Hemisphere were small and infrequent, averaging about every 10 years. In 1996, the pattern was broken when Bucharest reported nearly 400 human cases, with a case fatality rate of 10% (Malkinson et al., 2002). Since 1996, there has been some sort of outbreak of West Nile Virus each year, with 1999 marking the first occurrence in the Western Hemisphere.

Ornithophilic mosquitoes are the principal vectors in both the Eastern and Western Hemispheres, with many species of birds serving as the host/reservoirs and amplifying agents. A combination of peridomestic and migratory birds helps to maintain the disease cycle and viremic levels between outbreaks (Work, Hurlbut, and Taylor, 1955). Birds like the corvids—the crow family—are very susceptible to the virus, and readily succumb (Work, Hurlbut, and Taylor, 1955). In the United States, raptors are also extremely susceptible to the disease, and both corvids and raptors are used as indicators of local virus presence, while migratory birds spread the virus geographically (Rappole, Derrickson, and Hubalek, 2000).

Before plans for control measures can be made, it is important to locate and prioritize mosquito species, based on vector *competence* and *potential*. Vector *competence* is rated in the laboratory, and is based on two major criteria: in this case, the mosquito's susceptibility to West Nile Virus, and its capacity to pass the virus on to susceptible hosts, which then serve as viral reservoirs. Vector *potential* includes such criteria as the age of the species population, its host preference, feeding behavior, and population density (Sardelis et al., 2001).

Three general categories of North American vector mosquitoes have been identified and rated as to vector competence: highly effective vectors of the artificial-container-breeding species of the genera *Aedes* and *Ochlerotatus*; moderately effective *Culex* spp.; and inefficient vectors of the genera *Aedes* and *Ochlerotatus* that breed in floodwaters (Centers for Disease Control and Prevention, 1999; Sardelis et al., 2001). Because Monroe County has all of these mosquitoes and the domestic and migratory birds that are thought to be the reservoirs of the virus, the potential exists for West Nile Virus outbreaks here (Pennsylvania West Nile Virus Control Program, 2002).

Defining Elements and Components of a Model Integrated Vector Management Program for Mosquitoes

Rutgers University (2003) has succinctly defined IPM for mosquitoes as including an understanding of mosquito biology, identification, and bionomics; surveillance measures (the driving force behind all control decisions); comprehensive control measures, including chemical and non-chemical strategies; and an educational component for staff and the community.

Ideally, the elements of a model integrated vector management program would vary by locality to suit particular ecological, geographic, climatic, human population distribution, and socioeconomic characteristics; however, there should be a core set of components common to vector management programs, and these could include the following components:

- Administrative considerations and program operation—including administrative commitment, funding, logistics, and advocacy for the mosquito vector control program.
- IPM for mosquitoes, with the following elements: (1) Programmatic efforts to study and understand the biology and bionomics of local mosquito species; (2) Virus surveillance and monitoring that includes sentinel chicken testing, mosquito testing, and dead bird testing to detect viral activity in animal populations before it affects human health; (3) Qualified laboratory testing and analyses facilities for mosquito, bird, and equine samples that are also linked to data from testing of human beings; (4) Comprehensive mosquito control measures; and (5) Vigorous staff and public education, media cooperation, and community involvement leading to community buy-in and helping to ensure successful outcomes for the program's surveillance and control activities.

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- Active interaction with local universities—for providing technical support, interdisciplinary collaboration, and a core of prepared interns and seasonal help.
- Interagency collaboration including local, state, and federal agencies that encourage, support, finance, and provide platforms for public education.
- The application of new technologies like Internet/Web-based use of Global Positioning Systems (GPS) and Geographic Information Systems (GIS)—including Internet/Web-based surveillance data reporting and use of GPS coordinates and GIS maps to maximize the vector program's ability to actually pinpoint viral sample sources and locations.

Operational Implementation of a Model Program in Monroe County

Administrative Considerations and Program Operation

Structure of the Monroe County West Nile Virus Surveillance Program

Pennsylvania's Monroe County (in the heart of the Pocono Mountains, an intensely tourist-driven area) was, and continues to be, well ahead of the curve. The Department of Vector Control was established in 1973. It dealt with all aspects of mosquito and arthropod-borne disease surveillance and control through the years that followed. These services included arboviral surveillance for vector-borne diseases such as Eastern Equine Encephalitis (EEE), St. Louis Encephalitis (SLE), and Hanta Virus; vector and nuisance mosquito control using IPM strategies and public education; gypsy moth surveillance and control through the state's gypsy moth suppression program; and rodent surveillance and control, also using IPM measures of harborage, food reduction, and sanitation. Monroe County Vector Control also serves as an information source for many pest problems encountered by citizens, providing them with methods and equipment to deal with their problems if possible, or providing a referral service to private pest control or environmental laboratories.

The West Nile Virus Surveillance Program in Monroe County is a continuation of the Vector Control Program instituted in 1973. Even though there had not been a major outbreak of arboviral disease in decades, Monroe County had not abandoned vector control service. Because of the threat of Eastern Equine Encephalitis and St. Louis Encephalitis, Monroe County Vector Control had already documented the breeding areas of all local mosquito species later identified with West Nile Virus transmission. The Monroe County West Nile Virus Program is administered as an integral part of the county's functions, with support from several county agencies, including the Planning Commission, the Tax Assessor's Office, the Grants Office, and the Department of Information Services.

Legal Coverage through Interagency Collaboration

Legal coverage for operations of the surveillance activities is provided by interagency collaboration within the county. The Pennsylvania Department of Environmental Protection and local municipalities have regulations and public health codes that can be enforced to encourage cleanup of breeding sites on citizens' businesses or private properties.

Funding and Administrative Issues

The economy of the Pocono region is primarily tourism-driven, and the area politicians, community leaders, and businesspeople insist on a welcoming, comfortable outdoors. Consequently, politicians are willing to fund programs that contribute to making the outdoors more attractive. This includes reducing mosquito and black fly populations, eliminating litter and deer carcasses from area roadways, and spraying for gypsy moths when necessary. Aside from the aesthetic results of Program operations, the Monroe County Vector Control mandate has been to minimize or eliminate the risk of vector-borne disease to the 120,000 permanent residents and the hundreds of thousands of resort area visitors who pass through the area.

The Director of Monroe Vector Control provides oversight for West Nile Virus surveillance activities implemented by surveillance staff, including periodic interns from the local university. Funding for the West Nile Virus Surveillance Program is obtained from the county and state in the form of West Nile Virus surveillance grants and, when compared to the base county population, this works out to be about $1 per permanent resident. This dollar amount would be considerably less if computed on the much larger seasonal population. For comparison, several years ago, one shore community in southern New Jersey with a comparable permanent population spent around $14.40 per permanent resident and $2.24 per seasonal resident per year (Hansen, 1994).

Self-Assessment

On an ongoing basis, the Program conducts and benefits from a self-assessment and monitoring of its conformity with updated guidelines provided by the Centers for Disease Control and Prevention (2000) and Pennsylvania's Department of Environmental Protection. Calls and comments from the community are also analyzed to help improve Program performance. In addition, the Program is active in state and national vector control associations, both to provide support and to keep current with relevant local and state developments, initiatives, and benchmarks or standards for implementation in the Program.

Virus Surveillance, Monitoring, and IPM for Mosquitoes in Monroe County

Understanding Mosquito Biology: Staff Training

Understanding mosquito biology (and training staff to do so) includes developing the skills to understand mosquito biology, identification, and bionomics. Staff training begins by educating each staff member in species identification, bionomics and habitat characteristics, vector competence, vector potential, and sampling techniques. Training is done in the office, in the field, and at training seminars.

Virus Surveillance and Monitoring: Applying New Tools and Technologies

Surveillance begins in early spring, with the aggressive monitoring of larval vector populations. In addition to hundreds of natural wet areas, the Program monitors several hundred storm sewers, 32 tire sites, 50 wastewater treatment plants, and several dozen abandoned swimming pools. All wastewater treatment plants are monitored for adult mosquitoes and virus activity by light and gravid trapping, with samples sent to state laboratories in Harrisburg, Pennsylvania, for viral isolations. All mosquito samples are logged into the database according to GPS coordinates (Garmin International, 2000) and GIS maps (Environmental Systems Research Institute, 1996) to pinpoint the exact location of samples and/or treatment (Pennsylvania West Nile Virus Control Program [secure site], 2002).

The state retains all data regarding surveillance and control in this secure Web site, accessible only to authorized people in public health West Nile Virus work. Information is available to the public at the West Nile Virus Web page, which gives current statistics on statewide positive samples, health information, news bulletins, and animal health information, and which discusses strategies for reducing the risk of infection on a personal level (Pennsylvania's West Nile Virus Surveillance Program, 2003).

Data Collection and New Tools: Web-Based Logging of Mosquito Samples into the Database Using GPS and GIS

GPS is a relatively new tool that helps the field worker plot the exact location of a sample on a computerized GIS program. Not only can local staff return to these locations, but colleagues at the Department of Environmental Protection can also pinpoint each sample's location. The new secure Web site allows authorized public health staff to enter local Program data, retrieve data, view input from other counties, and collate important segments of the data. For example, the positive pool of mosquitoes collected in August 2002 was identified as *Culex pipiens*, consistent with previous research on vector species of West Nile Virus (Sardelis et al., 2001). This is especially noteworthy because *Culex pipiens* has been identified as the primary vector of West Nile Virus (Sardelis et al., 2001).

Sample Data from Surveillance Activities

Data are presented on the total number of adult mosquitoes collected by species and month of capture, collection methods, a sample of site and location by GPS, and primary habitat of the mosquitoes. Although 30 years of data are available, this article only presents and discusses the most recent full year of data.

Table 1 presents 18 sites in Monroe County from which any mosquitoes (larvae or adults) were collected in 2002. It provides a sample of GPS latitudinal and longitudinal coordinates for a day of fieldwork. Another important component of West Nile Virus surveillance is the compilation of taxonomy sheets that include pertinent ecological, environmental, and mosquito bionomic data (see Figure 1). The full information set compiled from one sample of adult mosquitoes is presented in Figure 1. This details the comprehensive nature of information logged into the computer for each sample collected in the field, including habitat, species, counts, and viral testing.

Table 2 shows that 8,700 adult mosquitoes were collected in Monroe County between January and October 2002, including overwintering females; *Culex* and *Anopheles* spp. overwinter and are capable of retaining West Nile Virus

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Table 1. Pennsylvania's West Nile Virus Control Program, Monroe County, 2002, selected mosquito sites, as located by Global Positioning Systems

Name	Latitude	Longitude	County ID
13 LN Edgemont	41.02455	−75.19896	45
40 4 Seasons Campground	41.06453	−75.33308	45
40 Babbling Brook Road	41.06882	−75.34072	45
40 Scotrun Motel	41.05516	−75.31647	45
45 Flory's Pond Gilliand 5	41.0078	−75.17206	45
45 Mountain Road 08	41.0143262	−75.33389977	45
45 A Pocono Country Place	41.19034	−75.37125	45
45 124 Sellersville Road 09	41.0677	−75.09142	45
45 125 Barnum Street	40.9991332	−75.18868247	45
45 20 Upper Lake View Drive 09	41.07293	−75.08473	45
45 238 Lee Street	40.98044	−75.1892	45
45 239 Lee Street	40.98044	−75.1892	45
45 245 Section FPEstates17	41.0275	−75.2478	45
45 30 Stillwater Drive 19	41.11999	−75.41221	45
45 314 West	41.1035	−75.35373	45
45 377 Bryant Street	40.9814737	−75.18454582	45
45 3 Lakeview Court 19	41.11619	−75.44747	45
45 3 Tamarack Terrace 19	41.11718	−75.41283	45

Source: Monroe County data, as compiled on Pennsylvania West Nile Virus Control Program, 2002.

USI:03502017529

Date Received	7/26/2002
County	MONROE
Municipality	C Twp
Surveillance. Type	Mosquito Light Trap
Virus Isolation. Performed ?	Y
Site name	45 T. Gravel Pit
Collected	7/25/2002
Collector	Charles T
Id Date	7/30/2002
Taxonomist	Sven. S.
Lab Comments	
Field Comments	
SITENAME	45T Gravel Pit
ADULT	11-100
Runtime	1600
PHABITAT	Wetlands
SHABITAT	Wooded Area
NUMTIRES	None
TIRETEXT	

Mosquito Species	Mosquito name	#Pupae	#larvae	# Adults	# eggs
99	*Coquillettidia perturbans*			7	
14	*Ochlerotatus canadensis canadensis*			17	
135	*Culiseta melanura*			1	
75	*Ochlerotatus triseriatus*			1	

Figure 1. Pennsylvania's West Nile Virus Control Program, Monroe County, 2002, taxonomy sample sheet showing typical data collected in field. (Source: Monroe County data, as compiled on Pennsylvania West Nile Virus Control Program, 2002.)

through the winter (Nasci et al., 2001). Seven genera of mosquitoes were collected in samples, including the identified competent vector species *Aedes vexans*, *Ochlerotatus japonicus*, *Ochlerotatus atropalpus*, *Anopheles punctipennis*, *Culex pipiens*, and *Culex salinarius*. Because only *Anopheles* and *Culex* females overwinter, the reader will note the absence of any other genera in the winter sampling (January to March). And as not all mosquitoes are capable of transmitting West Nile Virus, only certain species are of concern when surveillance indicates their populations are increasing. Seasonal fluctuations for potential vector species are graphically displayed in Figure 2. Overall, these adult mosquito counts shown in Figure 2 (year 2002) were low. *Culex pipiens* and *Culex salinarius* show peak numbers in August, coinciding with the peak transmission months of August, September, and October. *Culex restuans* was collected in higher numbers, with a peak in June. During the spring months of April, May, and June, there is a clear and high peak of the floodwater mosquito *Ochlerotatus trivittatus*. The artificial-container-breeding *Ochlerotatus triseriatus* shows bimodal peaks, first in April and again in July. *Aedes vexans* and *Ochlerotatus japonicus* make spring peaks in April, and *Anopheles punctipennis* remained low throughout the season. In summary, all vector species were kept at very low levels through the peak human transmission period of August through October.

The 2002 summary of West Nile Virus positive samples—mosquito, avian, mammal, and human—is shown in Table 3. Of almost 700 mosquito pools sampled, of which 251 were tested, only one pool of *Culex pipiens* reported positive for West Nile Virus in 2002. Twenty-two dead birds were collected, 18 were shipped for testing, and five tested positive (four crows and one kestrel). One veterinary sample, a horse brought in from out of the county, tested positive. There were no reported cases of West Nile Virus in humans (see Table 4).

Facilities for Laboratory Testing and Analysis

If an avian specimen fits certain parameters (species, interval from time of death, holding temperature, absence of parasites), it is picked up by Program staff and delivered to the State Department of Health for shipment to the laboratory. On average, there are 10 calls per week regarding dead bird sightings, and about one bird out of 20 called in is shipped for testing. Reports on all birds, shipped or not, are entered into the Department of Health Dead Bird Reporting Web site. The Program works with

Table 2. Mosquitoes collected for the 2002 season, Monroe County, Pennsylvania

Genus and species	Month collected										
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Totals
*Aedes vexan**	0	0	0	177	109	80	51	37	78	2	524
cinereus	0	0	0	53	31	28	24	14	0	0	140
*Culex pipiens**	0	0	2	2	2	14	25	130	24	4	203
*restuans**	0	0	0	38	55	639	167	116	71	2	1,088
*salinarius**	0	0	0	0	12	5	20	24	4	0	65
territans	0	2	0	0	0	5	1	1	0	0	9
erraticus	0	0	0	0	0	0	0	2	0	0	2
*Anopheles punctipennis**	77	42	27	5	18	4	12	42	6	2	235
quadrimaculatus	8	13	83	0	2	0	12	129	15	0	260
barberi	0	0	0	0	0	0	0	4	2	0	6
walkeri	0	0	0	0	0	2	0	3	0	0	5
crucians	0	0	0	0	0	0	0	2	0	0	2
Ochlerotatus atropalpus	0	0	0	0	0	1	0	1	0	0	2
aurifer	0	0	0	0	2	1	0	0	0	0	3
canadensis	0	0	0	88	23	662	512	86	0	0	1,372
communis	0	0	0	89	2	2	0	0	0	0	93
excrucians	0	0	0	6	0	6	0	0	0	0	12
fitchii	0	0	0	1	0	0	0	0	0	0	1
hendersoni	0	0	0	0	0	0	1	0	2	0	3
*japonicus**	0	0	0	141	1	76	147	56	39	20	480
provocans	0	0	0	0	0	0	1	0	0	0	1
sticticus	0	0	0	0	60	337	65	1	0	0	463
stimulans	0	0	0	10	0	13	9	0	0	0	32
*triseriatus**	0	0	0	147	20	110	151	81	13	5	527
*trivittatus**	0	0	0	0	1,415	454	101	46	6	0	2,022
Psorophora ferox	0	0	0	0	0	6	3	0	2	0	11
Coquillettidia perturbans	0	0	0	0	0	130	626	301	4	0	1,061
Culiseta inornata	0	0	0	0	0	0	1	0	1	0	2
melanura	0	0	0	8	2	6	13	8	1	0	38
morsitans	0	0	0	4	0	0	8	1	1	0	14
Uranotaenia sapphirina	0	0	0	0	0	0	0	7	17	0	24
Grand total, 2002											8,700

* Not all mosquitoes are capable of transmitting West Nile Virus. Seasonal fluctuations for the asterisked potential vector species of concern are also graphically displayed in Figure 2.

three other laboratories—the Pennsylvania Department of Agriculture tests equine samples, and the Department of Environmental Protection tests mosquito samples; the United States Geological Survey National Wildlife Health Center is also available for evaluating special or unusual wildlife specimens.

Comprehensive Control Measures

Monroe County continues efforts with IPM to keep mosquito populations down by minimal adulticiding and extensive larviciding with insecticides like bacterial products and methoprene. Control measures are instituted based on monitoring of mosquito population levels, species found, vector competence, and human proximity to breeding sites. When larval densities reach six or more vector or nuisance mosquito larvae per 350 ml, treatment is initiated. This threshold level has been determined from practical experience. Vector species of highest priority for control measures are *Culex pipiens*, *Culex restuans*, *Ochlerotatus japonicus*, *Aedes vexans*, and *Anopheles punctipennis*.

Human proximity to breeding sites is also a major concern, and the Program attempts to control mosquitoes in areas of high human habitation and recreational activity before doing work in areas that do not pose as direct a threat of human infection. Viral amplification and bird-

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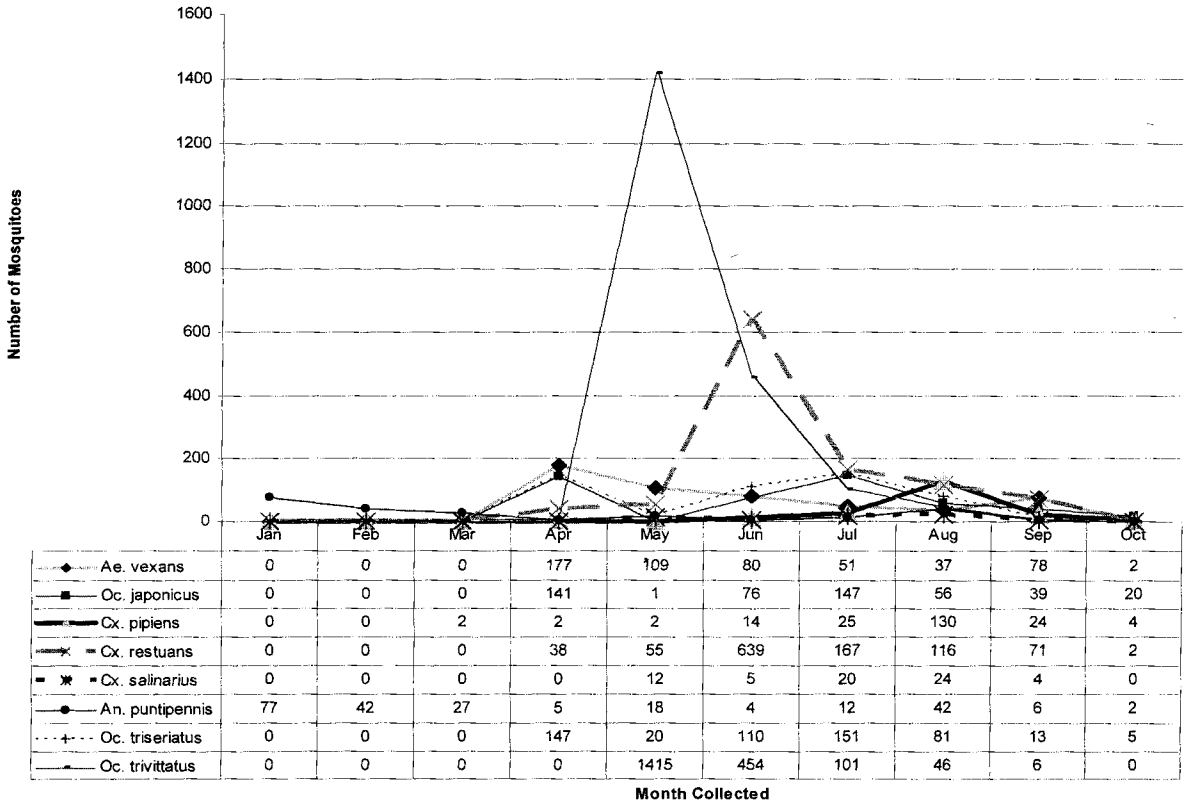

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Ae. vexans	0	0	0	177	109	80	51	37	78	2
Oc. japonicus	0	0	0	141	1	76	147	56	39	20
Cx. pipiens	0	0	2	2	2	14	25	130	24	4
Cx. restuans	0	0	0	38	55	639	167	116	71	2
Cx. salinarius	0	0	0	0	12	5	20	24	4	0
An. puntipennis	77	42	27	5	18	4	12	42	6	2
Oc. triseriatus	0	0	0	147	20	110	151	81	13	5
Oc. trivittatus	0	0	0	0	1415	454	101	46	6	0

Figure 2. Seasonal fluctuations for selected potential West Nile Virus vector species of concern collected for 2002 season, Monroe County, Pennsylvania. This graph can be correlated with the numbers in Table 2.

to-bird transmission by mosquitoes occurs in all areas, and remain a concern.

Control is usually limited to larviciding (treating the water to prevent the emergence of biting mosquitoes) with products such as *Bacillus thuringiensis israelensis* (*Bti*), *B. sphaericus* (*Bs*), and methoprene. *Bti* is applied to areas of clean water and univoltine (one generation per year) mosquito species. Because it works extremely well as a quick-kill and is quickly degraded, its use is carefully timed and monitored for maximum efficiency. *Bs* was formulated specifically for *Culex* spp., which tend to lay their eggs in water that is considerably higher in pollutants and organics. The *Bs* label and advertising claim that this bacterium reproduces in the larval cadavers and remains active in the treatment site for several weeks; it works quickly and efficiently against *Culex* and other species as well. Both bacteria produce toxins that must be ingested by feeding larvae. These toxins target the mid-gut, causing rupture. They are specific to certain Dipteran larvae and impact few non-target insects. Methoprene, a synthetic juvenile hormone, inhibits the final ecdysis from the pupal case, rather than poisoning the larva. Because methoprene is not a quick-kill product and must be ingested *before* the larva reaches its final instar, its use is determined by larval development as well as numbers. Methoprene is more persistent in the site, lasting from 30 to 150 days (depending on formulation), and works well for multivoltine (multiple generations per year) species and pretreatments.

In special circumstances, the Program uses monomolecular films or organophosphates designed specifically for use against mosquito larvae and pupae. These organophosphates, like temephos, are used only in artificial habitats that have no chance of contaminating natural water bodies, such as tire piles, unchlorinated pools, and some storm sewers. Monomolecular films kill by suffocating the air-breathing larvae and pupae, but will also kill non-target and beneficial aquatic insects; they are used only as an emergency measure to keep large numbers of pupae from emerging as adults.

As a treatment method, adulticiding—commonly known as "spraying"—is done judiciously and only when other control measures have failed. The decision to spray is based on vector species, population numbers, human

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Table 3. Monroe County, Pennsylvania, West Nile Virus surveillance summary 2002

Surveillance type	Number collected	Number tested	Number positives
Dead birds	22	18	5
Mosquito samples	692	251	1
Sentinel chickens and horses	1	1	1
Humans	NA	NA	0

Source: Monroe County data, as compiled on Pennsylvania's West Nile Virus Surveillance Program, 2003.

proximity, and viral presence. For adulticiding, the Program utilizes pyrethroid products using the Ultra Low Volume (ULV) system.

Other control strategies include the placement of native larvivorous fish into wet areas that are not suitable for larvicides, construction and placement of bat boxes, and source reduction. Source reduction includes the removal or mitigation of breeding sites: tire removal, redesigning of catch basins, drainage of construction sites, backfilling abandoned swimming pools, and proper maintenance of sewage treatment plants. The Program works with municipalities and the state to eliminate artificial container sites such as improperly maintained wastewater treatment plants, incorrect drainage at construction sites, poorly designed storm sewers, and tire piles. The Program recently won an award from the Governor's Office for its cooperation with a township in the removal and disposal of thousands of tires at an abandoned recycling site.

Vigorous Public Education and Involvement

There are many ways of disseminating information to or alerting the public, providing health education, and eliciting cooperation of the public. For example, the Program enlists and trains retired seniors, through the Retired Senior Volunteer Program (RSVP), to distribute Program literature at public events. Much effort has gone into educating the operators of local wastewater treatment plants to correct design flaws and increase agitation of surface water to assure the plants are not breeding mosquitoes. In response to the threat of West Nile Virus, one local municipality enacted a section to its nuisance ordinance to prohibit the outdoor accumulation of tires (and other materials suitable for mosquito breeding habitat) for more than three days between the months of March and October (Stroud Township, 2000). This ordinance has been shared with the other 19 municipalities in the county, with the hope that they will follow suit in their own nuisance codes.

Table 4. Monroe County, Pennsylvania, West Nile Virus positives reported in 2002*

Municipality	Date	Animal type
Municipality 12	8/29/2002	American crow
Municipality 9	8/29/2002	American crow
Municipality 17	9/19/2002	Mosquito
N/A	10/4/2002	Equine
Municipality 9	10/24/2002	American crow
Municipality 18	10/25/2002	American crow
Municipality 2	10/28/2002	Kestrel

* No human cases were reported.
Source: Monroe County data, as compiled on Pennsylvania's West Nile Virus Surveillance Program, 2003.

Helping Residents to Identify/Abate Breeding Sites/ Risks on Their Own Properties

Another educational component of the Program is helping residents identify breeding sites and risks on their own properties. Any container, natural or artificial, that holds water for more than seven days during the peak season is a potential mosquito breeding site, depending on ambient temperature. Natural areas are more likely to contain other organisms that continuously control mosquito proliferation by parasitism and predation. Artificial containers lack these predators and parasites and are often the choice of the very species of mosquitoes that have the highest potential for transmitting West Nile Virus (Nasci, 2001). In addition, members of the Program staff provide personal protection strategies, including the use of repellents, the wearing of appropriate clothing, avoiding active mosquito-biting times of day, and making sure that window and door screens are in good repair and fit tightly. The Program has created a two-page handout for homeowners/ residents with information about mosquitoes and how to minimize the risk of mosquito breeding around the home (see Figures 3 and 4). This brochure is given to everyone who comes into the office bringing a tick or insect for identification, is mailed to every caller who inquires about mosquitoes or West Nile Virus, and is distributed at all expositions that the Program staff attends.

Program staff members are often invited by local organizations to give educational seminars on West Nile Virus and other vector-borne diseases. The regional television stations, radio and newspapers, and the Pennsylvania State University's Cooperative Extension Service provide platforms and forums for dissemination of information about Monroe County Vector Control's work and research. In addition, members of the Program staff have been invited to conferences all over the United States to share this work

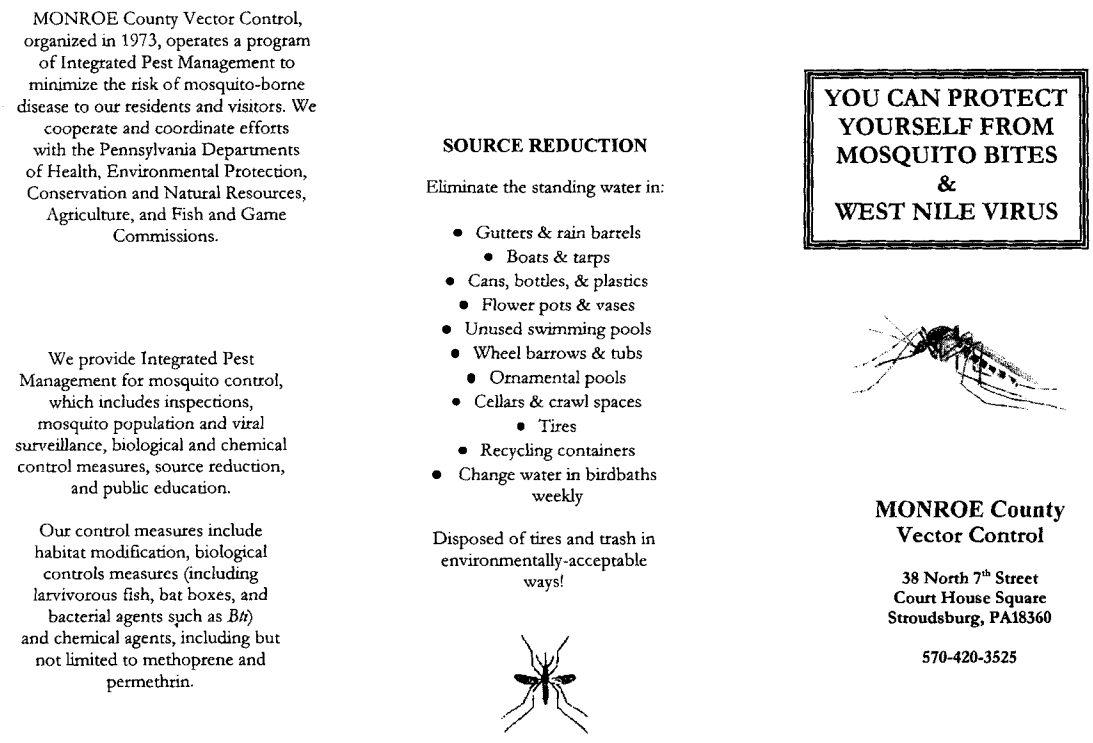

Figure 3. West Nile Virus public education brochure, Monroe County, Pennsylvania, page 1.

with professional colleagues in vector control and environmental health. Monroe County Vector Control is involved with and has presented at scientific meetings of national and state level voluntary health agencies such as the American Mosquito Control Association (AMCA), Pennsylvania Vector Control Association (PVCA), National Environmental Health Association (NEHA), Society for Vector Ecology (SOVE), Environmental Section of the American Public Health Association (APHA), and Society for Public Health Education (SOPHE).

Home-schoolers are brought to the Vector Control office by their parents to fulfill science requirements; at such educational sessions, staff members always include information about West Nile Virus and other arthropod-borne diseases. The Program has also made a special effort to reach seniors in the community—an "at risk" population—by partnering with the Area Agency on Aging to bring risk-reduction education to the senior centers of the county. In 2000 and 2002, Program staff visited five senior centers, and after each information session, participants were surveyed for their level of West Nile Virus knowledge. Intervention strategies were also presented, including brochures and health education regarding the avoidance of mosquitoes and minimizing personal risk (Bitto, Hakim, and Pula, 2002).

Community Partnerships: Reports from the Public

The entire community is now partnering in surveillance activities. Calls from the public regarding mosquitoes are followed up with a field investigation. Calls about dead birds are triaged by Vector Control to determine condition and species of bird, as the State Department of Health will only test birds that die readily from West Nile Virus and that make good indicators, such as corvids and raptors.

Community Partnerships: Mass Media

Another important aspect of community partnerships is the work with local news media outlets. The Director of Monroe County Vector Control is often interviewed by the media for an up-to-the-minute report on what is happening in Monroe County regarding vector-borne diseases. Television, radio, newspapers, and other publications help inform communities of the role of Vector Control, and they also help with educating the public. For example, Merle Ruben (1999) of the *Pocono Shopper* reported:

> For 25 years, Jacqui and her department have been responsible for monitoring and controlling the vector populations of Monroe County . . . . On a daily basis,

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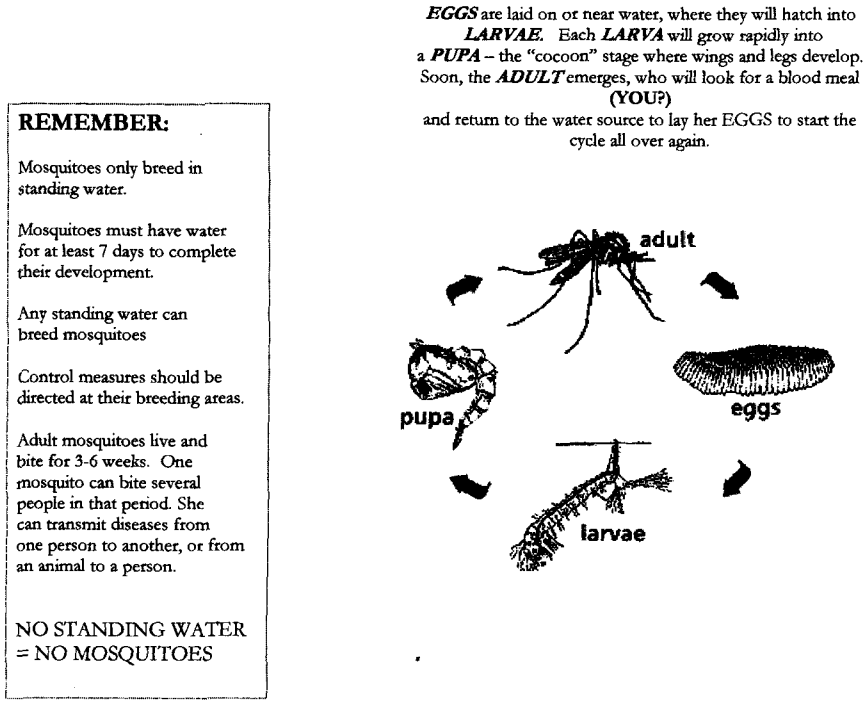

Figure 4. West Nile Virus public education brochure, Monroe County, Pennsylvania, page 2.

> Vector Control monitors the mosquito population, identifying the species and breeding grounds, then destroying them. By treating the water where mosquitoes live as larvae, we can control the majority of the mosquito population. Mosquitoes breed in still water, like swamps, dirty birdbaths and old tires, anywhere where water collects.

These messages are reiterated in every interview, story, and press release. The Program encourages and sustains media cooperation by being forthright, interesting, and available at all times.

Active Interaction with East Stroudsburg University

Interaction with East Stroudsburg University provides one way to keep in touch with teaching, training, student-interns/new employees, and new research. Monroe County Vector Control has partnered with East Stroudsburg University for summer workers and interns, which has allowed college students to obtain experience in vector control and a salary while working toward their degrees. In addition, the Health Department Epidemiologist has been extremely helpful in research design, data collection, statistical analyses, and research reporting. The Biology Department cooperates by aiding in the training of staff, performing some laboratory work, and, occasionally, providing insect identifications.

Other Interagency Collaboration, Including Local, State, and Federal Agencies

Interagency collaboration including local, state, and federal agencies is an essential component of the Program. The State Department of Health maintains the Dead Bird Reporting Web site, the Pennsylvania Department of Agriculture oversees the mammal and avian sentinel program, and the United States Geological Survey National Wildlife Health Center is also available for testing of specimens.

The major collaborator, the Department of Environmental Protection, has made grant money available to start-up mosquito surveillance and control programs throughout the state. Most counties had no established programs prepared to deal with arboviral disease control and were at a severe disadvantage starting out in West Nile Virus surveillance and control. Recent special funding has allowed Monroe County Vector Control to upgrade its 30-year-old Program with state-of-the-art technologies. Few at the state had actual field experience with mosquitoes and mosquito control, and the Program's historical perspectives, expertise, and experience in the field allowed its staff considerable input into the design and initiation of Pennsylvania's West Nile Virus Program in 2000.

As already stated, interagency cooperation between the local municipalities, the state, and Monroe County Vector Control has been critical to the Program's mosquito

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control efforts. Without this support, the Program would not have been able to dispose of thousands of tires, work with municipalities to redesign storm sewers and retention basins, monitor wastewater treatment plants, or encourage builders to mitigate their sites to prevent water accumulations.

Monroe County Vector Control has partnered with the Pennsylvania Department of Welfare for summer workers, which has allowed welfare mothers to continue receiving benefits while doing community service in mosquito control. Local municipalities refer their residents for mosquito control and mitigation services, and members of the Program staff assist municipalities in obtaining state grants for tire pile removal and disposal costs. The National Park Service allows access to monitor and collect mosquitoes on federal lands by permit on a monthly basis. Members of the Program staff monitor mosquito populations on the local US Army Depot and work with their environmental staff in control efforts (if and when necessary). At the state level, the Department of Transportation assists in source reduction activities by receiving waste tires that are found during the course of fieldwork.

Discussion

Lessons Learned

The West Nile Virus Educational Program is reaching many elements within the community, but it is missing some. The most efficient but expensive and time-consuming method to convey information is one-on-one, in which the Program staff explains mosquito breeding issues and identifies breeding sites right in residents' yards.

Another challenge that confronts public health workers is the interface of personal property rights versus the public good. In particular, in the case of vector mosquito control, the role of the staff is to enter private property to mitigate mosquito breeding (it is hoped, with the consent of the property owner). But this is not always possible; it may then be necessary to ask for the cooperation of municipal officers to enforce public health and nuisance codes or the state's regulations on solid waste management.

Yet another challenge encountered by the Program occurs with unseasonable rains that lead to unusual numbers of mosquito larvae needing simultaneous control measures.

Successes

Most Pennsylvania counties had no established programs prepared to deal with arboviral disease control, and were at a severe disadvantage starting out in West Nile Virus surveillance and control. In contrast, Monroe County's 30-year Program had logged information continuously on treatment areas, species found, rainfall and climatological data, chemical usage, and other arboviral surveillance data and techniques to help in the fight against a new mosquito-borne enemy. This expertise and experience in the field allowed the Program considerable input into the design and initiation of the state's West Nile Virus Program. Monroe County Vector Control has also served as a springboard for many assistants and interns who have gone on to direct county vector control programs in other states and counties.

This article illustrates how comprehensive vector control measures, including environmentally friendly ways of dealing with the problem and IPM, interagency collaboration, ways of disseminating information to/alerting the public, health education, and cooperation with the public have worked to minimize the risk of arthropod-borne disease in Monroe County, Pennsylvania. Many of the areas that were monitored and treated in the past have been eliminated through comprehensive source reduction and mitigation of mosquito breeding sites.

For several years, and until the late summer of 2002, all county samples had tested negative for West Nile Virus. The first positives were two crows, shipped in late August; the first and only positive mosquito sample pool was shipped in mid-August. That sample size was 13 mosquitoes, one of many (but small) samples from a large tire pile. Because of the low numbers of mosquitoes observed throughout the season, however, these did not present a health risk to the community. Up until the end of year 2002, there were no human infection cases, although the first (and only, to date) human case was reported in September 2003.

What are some possible determining factors for the observed low number of positives? It may be inferred that 30 years of continuous IPM along with mosquito surveillance, monitoring, and comprehensive control measures, combined with educating the public about ways to participate in mosquito control, have been major determining factors.

Recommendations for New West Nile Virus Programs

Implications for Practitioners

West Nile Virus has now been detected in most of the continental United States, with the West Coast's (California) first human case in 2002. According to Centers for Disease Control and Prevention data on case information for October 3, 2003, all but five states have reported human cases of West Nile Virus; an additional state reported only animal infections (Centers for Disease Control and Prevention, 2003). In 2002, the United States had 4,156 documented cases and 284 deaths from West Nile Virus in 39 states. The 2003 data indicate that nearly every community is at risk, and must contend with the near certainty that this virus will persist in the Western Hemisphere.

Technical Considerations

A plan of action for the environmental health professional would begin with familiarity with the local vector species, their bionomics, taxonomics, and the ability to make accurate mosquito identifications. By knowing the particulars about the local species of interest, it is possible to identify the correct times and areas for surveillance and control measures.

The next step is surveillance using larval sampling, and adult sampling with light traps and gravid traps. Global Positioning Systems (GPS) and Geographic Information Systems (GIS) are available in hand-held devices and computer programs to plot the data collected in the field accurately. This allows staff to return to the exact location where samples were previously collected, if control is necessary. After sampling, identification, and mapping, the information is available for devising a systematic method for identifying mosquito problem areas with regard to local mosquito vector species and population densities.

The third step would be to plan bio-rational control measures based on the data collected in the field: habitat, species, population levels, time of year, and vector potential. For example, univoltine (single generation) early spring mosquitoes like many *Ochlerotatus* spp. can usually be controlled with one larviciding treatment. Multivoltine (multiple generations) spp. like *Aedes vexans* need continuous monitoring throughout the middle and later portion of the season. *Culex pipiens* can best be controlled by attention to some of its common breeding sites: discard or store the tires, clean the rain gutters, turn over the buckets and wheelbarrows, and cover the rain barrels.

The last step involves evaluating the results of control measures and the numbers of viral isolations and making the necessary adjustments to control methods.

Educational Initiatives

Public health educators should be involved to disseminate information to the public, regarding measures being taken by the agency and strategies to be used by the citizen to minimize or eliminate mosquito breeding sites around the home or office. These can include mailing inserts in utility bills, brochures, newspaper articles, television and radio interviews, and public service announcements. Also, health fairs, community events, and school programs allow access to large populations and provide opportunities for distributing fliers or Program materials.

Building Bridges

The mosquito control agency needs to continuously reach out to other agencies and departments to implement certain aspects of the control work, such as identifying others who can help with mitigation work, educational outreach, grant writing, nuisance and vector control ordinances, and technical support.

As an ongoing process of keeping the public aware of the West Nile Virus situation in Pennsylvania, several hotlines and Web sites are also now available for general information and recommendations. There are pages specifically for the physician and the public health care practitioner. The Centers for Disease Control and Prevention have many pages of information on West Nile Virus, including how to recognize symptoms, how to avoid mosquito exposure, and where cases have been reported (see Table 5).

Conclusions

New vector-borne diseases are emerging across the United States. Many counties have no established programs prepared to deal with this aspect of public health, and are at a severe disadvantage starting out in surveillance and control of a disease like West Nile Virus. This article discusses how comprehensive vector control measures, including IPM, interagency collaboration, health education, and cooperation of the public can be implemented to

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Table 5. West Nile Virus Web sites and hotlines

Organization/agency	Web site address or telephone number
Centers for Disease Control and Prevention (for surveillance initiatives)	http://www.cdc.gov/ncidod/dvbid/westnile/surv&control.htm
Centers for Disease Control and Prevention (for answers to frequently asked questions)	http://www.cdc.gov/ncidod/dvbid/westnile/q&a.htm
US Geological Survey	http://westnilemaps.usgs.gov
State of Pennsylvania	http://www.westnile.state.pa.us http://www.agriculture.state.pa.us/animalhealth
Pennsylvania Department of Health Hotline	1-877-PA-HEALTH

help minimize the risk of West Nile Virus and other arthropod-borne viruses. Because staffing is one of the most expensive aspects of program operations, new programs should consider several possible alternatives including college interns, welfare recipients or other social service volunteers, court-remanded participants, and retired senior citizens as office staff/peer health educators.

Readers are encouraged to resist the seductive idea that certain infectious diseases have been conquered. Whereas many communities had disbanded their arthropod-borne disease units to save scarce resources (Steinhauer, 1999), Monroe County Vector Control remained funded. Thus, one of the novel aspects of Monroe County Vector Control is its sheer longevity in protecting public health over three decades. The work done in Monroe County can be replicated, at modest cost, in any local health department, cooperative extension office, or department of environmental services.

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