West Nile Virus Infection in Humans

Anne Kjemtrup, DVM, MPVM, Ph.D.
California Department of Health Services
Vector-Borne Disease Section
Introduction

- WNV responsible for largest encephalitis virus outbreak in U.S. history
  - Large amount of recent research on an organism that was identified in 1947
  - Today you will hear about personal perspectives of the disease
  - My objective is to give the larger public health picture and present some of the recent findings, both from California studies and recent literature
The Public Health Perspective of WNV

- Surveillance
- Clinical Disease and Outcome
- Treatment
- Prevention
Surveillance
Reporting WNV infections

(+) WNV Result from Commercial Lab / Blood banks

(+) WNV Result from Local/State Lab

CMR from Provider

Local Health Dept

- Investigate
- Arrange for additional testing if necessary
- If meets case def, complete case hx

- Fax or mail case hx to CDHS-VRDL

CMR entered into AVSS or local system

CDHS Surveillance and Statistics Section

Case reported to CDC via ArboNET

Case added to line list on www.westnile.ca.gov
West Nile Virus Activity in California Counties 2006 YTD

- Human cases: 276
- Horses: 58
- Dead birds: 1,446
- Mosquito samples: 832
- Sentinel chickens: 641
- Squirrels: 32

Updated 1/26/07
N = 36 counties with human cases

- Counties with West Nile virus activity (no human cases)
- Counties with West Nile virus activity (number of human infections)
<table>
<thead>
<tr>
<th>County</th>
<th>Incidence per 100,000 population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glenn</td>
<td>45.4</td>
</tr>
<tr>
<td>Colusa</td>
<td>21.3</td>
</tr>
<tr>
<td>Modoc</td>
<td>21.2</td>
</tr>
<tr>
<td>Yolo</td>
<td>16.0</td>
</tr>
<tr>
<td>Butte</td>
<td>15.3</td>
</tr>
<tr>
<td>Sutter</td>
<td>15.2</td>
</tr>
<tr>
<td>Tehama</td>
<td>10.7</td>
</tr>
<tr>
<td>Yuba</td>
<td>8.3</td>
</tr>
<tr>
<td>Mono</td>
<td>7.8</td>
</tr>
<tr>
<td>Kern</td>
<td>7.4</td>
</tr>
<tr>
<td>Lake</td>
<td>3.4</td>
</tr>
<tr>
<td>Placer</td>
<td>3.2</td>
</tr>
<tr>
<td>Stanislaus</td>
<td>2.5</td>
</tr>
<tr>
<td>Shasta</td>
<td>2.5</td>
</tr>
<tr>
<td>Merced</td>
<td>1.9</td>
</tr>
<tr>
<td>Tulare</td>
<td>1.6</td>
</tr>
<tr>
<td>Solano</td>
<td>1.5</td>
</tr>
<tr>
<td>San Joaquin</td>
<td>1.4</td>
</tr>
<tr>
<td>Fresno</td>
<td>1.4</td>
</tr>
<tr>
<td>El Dorado</td>
<td>1.3</td>
</tr>
<tr>
<td>Sacramento</td>
<td>1.2</td>
</tr>
<tr>
<td>Nevada</td>
<td>1.1</td>
</tr>
<tr>
<td>Others</td>
<td>&gt; 0</td>
</tr>
</tbody>
</table>

Statewide: 0.8 per 100,000
2006 West Nile Virus Activity in the United States
(Reported to CDC as of January 3, 2007*)

Indicates human disease case(s).

Avian, animal or mosquito infections.
2006 West Nile Virus
Human Neuroinvasive Disease
Incidence in the United States
(Reported to CDC as of January 3, 2007)
Updated (1/26/07)

California Human West Nile Virus Cases 2004-2007
(Week of Report)

Positive Humans

Date

0 20 40 60 80 100 120 140

2004
2005
2006
2007
Reported Incidence of Human West Nile Virus Illness, California and United States, 2003-2006

Incidence per 100,000 population

Year

2003 2004 2005 2006

California

US
Recent Findings

- New tests may make detection easier, more rapid, and give a better estimate of true incidence
  - Spectral’s Rapid 1 WNV test may make rapid patient identification easier
Recent Findings

Blood donor screening data may provide additional estimates of WNV incidence under some circumstances. (Busch et al., EID, March 2006)

- In 2003, 9,862 WNV cases were reported to ArboNet. If 2003 incidence of blood bank WNV-positive donors extrapolated to population, then an estimated 735,000 (322,000 – 1,147,000) infections may have occurred.
Recent Findings

► Busch et al., EID, March 2006

Note that geographical impact of WNV remains the same in 2003, regardless of the estimate used (reported cases vs. infection incidence).

Figure 4. A) Projected number of West Nile virus (WNV) infections per 1,000 persons. B) Estimated total number of WNV infections per state during 2003 epidemic season.
Recent Findings

- Seroprevalence studies have demonstrated increased population WNV prevalence following epidemics
  - 2.6% (NYC 1999) - 19.2% (Nebraska 2006)
    - Differences attributed to geographical differences such as greater abundance of *C. tarsalis* in NB.
  - In one study, ¾ of the cases identified through active surveillance were homeless individuals
    - Homeless individuals represent a population at risk for infection
Implications for Human Case Surveillance

► Obvious:
  ▪ Direct Prevention and Control Activities
    ▷ Identification of populations at risk to target education intervention
    ▷ Identification of geographic areas for mosquito control
  ▪ Monitor seasonality over time
    ▷ Planning for future years

► Not-so-obvious
  ▪ To screen or not to screen blood donor supplies (cost vs. risk)
  ▪ Develop future vaccination strategies (benefit vs. risk)
Clinical Disease And Outcomes
The “Pyramid Picture” Has Not Changed

- ~80% Asymptomatic
- ~20% West Nile fever
- <1% WNND
- ~10% of WNND are fatal (<0.1% of total infections)
# Human WNV Activity, 2006

WNV cases* reported in California as of February 2, 2007 (n=276)

<table>
<thead>
<tr>
<th>Sex</th>
<th>Number</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>177</td>
<td>(64)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age, in years</th>
<th>Number</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;18</td>
<td>13</td>
<td>(5)</td>
</tr>
<tr>
<td>18-44</td>
<td>93</td>
<td>(34)</td>
</tr>
<tr>
<td>45-64</td>
<td>114</td>
<td>(42)</td>
</tr>
<tr>
<td>65 and older</td>
<td>52</td>
<td>(19)</td>
</tr>
<tr>
<td>Median age, all cases</td>
<td>49</td>
<td>(range: 8-86)</td>
</tr>
<tr>
<td>Median age, neuroinvasive cases</td>
<td>53</td>
<td>(range: 14-86)</td>
</tr>
</tbody>
</table>

* Cases of illness in California residents with infection likely acquired in California
## Human WNV Activity, 2006

WNV cases* reported in California as of February 2, 2007 (n=276)

<table>
<thead>
<tr>
<th>Clinical presentation</th>
<th>Number</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neuroinvasive disease</td>
<td>82</td>
<td>(30)</td>
</tr>
<tr>
<td>Encephalitis/meningoencephalitis</td>
<td>37</td>
<td>(45)</td>
</tr>
<tr>
<td>Meningitis only</td>
<td>41</td>
<td>(50)</td>
</tr>
<tr>
<td>Acute flaccid paralysis^</td>
<td>8</td>
<td>(10)</td>
</tr>
<tr>
<td>Other/unknown neuroinvasive</td>
<td>3</td>
<td>(4)</td>
</tr>
<tr>
<td>West Nile fever</td>
<td>189</td>
<td>(68)</td>
</tr>
<tr>
<td>Unknown clinical presentation</td>
<td>5</td>
<td>(2)</td>
</tr>
<tr>
<td><strong>WNV-associated fatality</strong></td>
<td>7</td>
<td>(3)</td>
</tr>
</tbody>
</table>

* Cases of illness in California residents with infection likely acquired in California
^ One case presented with acute flaccid paralysis only
Incidence of WNV Illness, by Age and Clinical Presentation
California, 2006 - reported as of December 1, 2006 (n=272)

* 2000 U.S. Census Data
## Preliminary Univariate Analysis (2006): Risk Factors for Developing WNND vs. WN Fever

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>WNF n (%)</th>
<th>WNND n (%)</th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes</td>
<td>9 (7)</td>
<td>12 (20)</td>
<td>3.60</td>
<td>1.43 - 9.10</td>
</tr>
<tr>
<td>Age (&gt;64 years)</td>
<td>24 (13)</td>
<td>25 (31)</td>
<td>2.96</td>
<td>1.56 - 5.60</td>
</tr>
<tr>
<td>Hypertension</td>
<td>36 (26)</td>
<td>26 (44)</td>
<td>2.25</td>
<td>1.19 - 4.27</td>
</tr>
<tr>
<td>Gender (male)</td>
<td>114 (62)</td>
<td>56 (69)</td>
<td>1.36</td>
<td>0.78 - 2.37</td>
</tr>
</tbody>
</table>
Are some people more at risk for disease?

A Genetic basis for human susceptibility to WNV (Diamond et al., Trends In Microbiology 2006)

- Suggests that a genetic mutation normally protective against infection with HIV-1, increases risk of fatal WNV infection.
- Mutation more common among N. American Caucasians
- Showed up > 5,000 years ago
Genetic basis for WNV disease susceptibility

- Intriguing: an allele that gives almost complete protection against 1 disease but enhances susceptibility for another

- People with this variant appear more prone to fatal WNV infection than those without. Does not explain age issue and other genetic issues.

- Although CCR5 may be logical target for new drug development in HIV/AIDS, the benefits of blocking CCR5 could carry cost of increased risk of WNV disease in co-infected patients.
Children and WNV

► Though risk of WNV infection higher in children than adults, risk of WNND in children lower than adults.

► Most children with uncomplicated WNF recover within several days to weeks. (Hayes NB, PID, 2006)

► A review of pediatric cases from L.A. County found that pediatric patients reported rash more commonly than in adult patients (Civen R. et al, PID, 2006)
California Pediatric WNV Cases: 2004-2005
LJ Christie, SS Gavali, C Jean, S Honarmand, CA Glaser

A survey of outcomes was developed and implemented for both WNF and WNND in California pediatric patients from 2004 and 2005.

Figure 1: 2005 West Nile virus cases, by age

- 19 - 44: 29%
- 45 - 64: 44%
- 65 - 74: 13%
- 75+: 10%
- 0 - 18: 4%
## Table 1: Pediatric and Adult West Nile Virus Disease by syndrome (2004-2005):

<table>
<thead>
<tr>
<th>Clinical presentation</th>
<th>Pediatric N=72</th>
<th></th>
<th>Adult N=1584</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>(%)</td>
<td>n</td>
<td>(%)</td>
</tr>
<tr>
<td>West Nile fever</td>
<td>41</td>
<td>(59)</td>
<td>876</td>
<td>(61)</td>
</tr>
<tr>
<td>Meningitis</td>
<td>15</td>
<td>(22)</td>
<td>306</td>
<td>(21)</td>
</tr>
<tr>
<td>Encephalitis</td>
<td>10</td>
<td>(10)</td>
<td>200</td>
<td>(14)</td>
</tr>
<tr>
<td>Acute flaccid paralysis*</td>
<td>6</td>
<td>(9 )</td>
<td>59</td>
<td>(4)</td>
</tr>
<tr>
<td>Unknown</td>
<td>3</td>
<td>(4 )</td>
<td>143</td>
<td>(9)</td>
</tr>
</tbody>
</table>

* Acute flaccid paralysis may occur with other clinical presentations.
California Pediatric WNV Cases: 2004-2005

Results (continued)

► Significant WNV disease does occur in the pediatric population but less frequently than in adults.

► Pediatric patients with WNV presented with significantly more headache ($p=0.02$) and rash ($p=0.03$) than adults.

► WNF patients in general do well, returning to baseline functioning within a few weeks to months.

► Persistent headaches are a concern in WNF pediatric patients.
California Pediatric WNV Cases: 2004-2005

Results (continued)

- WNND pediatric patients typically returned to baseline within a few months.
  - Psychosocial impairments lasting months in pediatric WNND patients are concerns, especially in encephalitis patients.
- Recall bias and baseline functioning can affect results.
- Ongoing surveys are being evaluated for pediatric patients from the 2006 WNV season.
Transplacental/Transmammary Transmission?

- First possible congenital cases described 2002
- 2003 – 2004 study reported on 77 women infected with WNV during pregnancy (O’Leary et al., Pediatrics 2006)
  - 71 delivered total of 72 live infants
    - 7 had major malformations, 3 of whom had defects that could have been caused by maternal WNV infection. No greater incidence of malformations in this group than in general population. No conclusive evidence for WNV infection as cause.
  - 4 miscarriages
  - 2 elective abortions
  - 2/42 breast milk + for WNV RT-PCR. 1 breast-fed infant followed up and remained negative at 7 months.

- No conclusive evidence for transplacental/ transmammary transmission
Encephalitis Outcome Study
Shilpa Gavali-Jani, VRDL

- 92 WNV 2004-2005 encephalitis cases requested to complete activities of daily living questionnaire at 3, 6, 12 months after hospital admission for WNV encephalitis.
  - 62 (67%) individuals completed at least one survey.
  - Demographics, clinical and laboratory findings, similar between responders and non-responders except that more females than males responded.
Encephalitis Outcome Study

- 14/112 (13%) of individuals eligible for follow-up had died.
- Of the 30 non-responders, at least had 1 died.
- By 12 months of follow-up, most people were living at home independently.
Many patients reported worsened neuropsychological functioning at 6 or 12 months compared with 3 months.

<table>
<thead>
<tr>
<th>New Problem (Example)</th>
<th>3 month (N=36)</th>
<th>6 month (N=44)</th>
<th>12 month (N=51)</th>
</tr>
</thead>
<tbody>
<tr>
<td>depression</td>
<td>28%</td>
<td>20%</td>
<td>37%</td>
</tr>
<tr>
<td>problems finding the right word</td>
<td>25 %</td>
<td>39 %</td>
<td>41 %</td>
</tr>
</tbody>
</table>
Encephalitis Outcome Study
Conclusions

- Recovery of neurologic function is maximal during the first 3 months after hospitalization.

- Several psychological/social measures worsened over time and conferred significant morbidity in this population.

- Findings similar to findings from the Tennessee Unexplained Encephalitis Study’s unpublished results.
WNV Fever Follow-up, 2004


- WNV fever case participants contacted within 2, 3 and 9 months of onset.
  - Participants were queried about their acute and persistent symptoms.
  - Once a participant stated they were “100% back to normal” or reported no continuing or new symptoms, follow-up was discontinued.

- Participating Counties:
  - Fresno
  - Kern
  - Orange
  - Riverside
  - San Bernardino
2004 Follow-Up
Frequency of Reported Symptoms

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Initial (n=151)</th>
<th>Intermediate (n=114)</th>
<th>Final (n=37)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue</td>
<td>85%</td>
<td>70%</td>
<td>80%</td>
</tr>
<tr>
<td>Headache</td>
<td>90%</td>
<td>80%</td>
<td>90%</td>
</tr>
<tr>
<td>Fever</td>
<td>80%</td>
<td>70%</td>
<td>80%</td>
</tr>
<tr>
<td>Muscle weakness</td>
<td>70%</td>
<td>60%</td>
<td>70%</td>
</tr>
<tr>
<td>Muscle aches</td>
<td>60%</td>
<td>50%</td>
<td>60%</td>
</tr>
<tr>
<td>Rash</td>
<td>50%</td>
<td>40%</td>
<td>50%</td>
</tr>
<tr>
<td>Trouble walking</td>
<td>40%</td>
<td>30%</td>
<td>40%</td>
</tr>
<tr>
<td>Anorexia</td>
<td>30%</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td>Mental status change</td>
<td>20%</td>
<td>10%</td>
<td>20%</td>
</tr>
<tr>
<td>Eye pain</td>
<td>10%</td>
<td>0%</td>
<td>10%</td>
</tr>
<tr>
<td>Swollen glands</td>
<td>5%</td>
<td>0%</td>
<td>5%</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>5%</td>
<td>0%</td>
<td>5%</td>
</tr>
<tr>
<td>Sensitivity to light</td>
<td>5%</td>
<td>0%</td>
<td>5%</td>
</tr>
</tbody>
</table>
Medium Duration of Symptoms in WNV Patients, California and Illinois* Studies Compared

Symptom

- Diarrhea
- Fever
- Light sensitivity
- Eye pain
- Headache
- Rash
- Headache
- Swollen gland
- Muscle aches
- Fatigue
- Anorexia
- Mental change
- Muscle weakness
- Days to normal

Days

California
Illinois

*Watson JT et al. Ann Intern Med 2004; 141:360-5*
WNF Outcome Issues to Address

► How can quality of life issues be addressed more quantitatively?
► How does recovery from WNV fever compare with recovery from other illnesses with similar initial presentations?
► How can potential for recall bias be minimized?
Case-Control Study

► Unmatched case-control study

► **Case**: a person with a fever-like illness who tested positive for West Nile and did not have encephalitis, flaccid paralysis, or aseptic meningitis

► **Control**: a person with a fever-like illness who tested negative for West Nile and did not have encephalitis, flaccid paralysis, or aseptic meningitis

Study made possible by helpful participation from local health departments.
WNF Follow-Up 2005-2006

Methods

► Initial survey
  ► Contact, consent and establishment of symptoms at onset obtained

► 3 month and 1 year follow-up surveys
  ► Quality of life assessment (SF-36)
  ► Scores can be compared between cases and controls as well as between cases and the general U.S. population
WNF Follow-Up 2005-2006

Methods

► 36-item Short-Form General Health Survey (SF-36): standardized quality of life assessment tool
  ► Used in the 2 and 9 month surveys
  ► Measures participants’ perceived:
    ► Physical functioning
    ► Physical health
    ► Bodily pain
    ► General health
    ► Vitality
    ► Social functioning
    ► Emotional status
    ► Mental health
## WNF Follow-Up 2005-2006
### Initial Results

<table>
<thead>
<tr>
<th></th>
<th>Interview 1 (1-2 mo)</th>
<th>Interview 2 (2-3 mo)</th>
<th>Interview 3 (9-12 mo)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of Participants</strong></td>
<td>Case: 204</td>
<td>Control: 34</td>
<td>Case: 152</td>
</tr>
<tr>
<td><strong>Age Range (Mean)</strong></td>
<td>18-88 (51)</td>
<td>20-83 (47)</td>
<td>18-88 (53)</td>
</tr>
<tr>
<td><strong>% Female</strong></td>
<td>51%</td>
<td>59%</td>
<td>52%</td>
</tr>
</tbody>
</table>
WNF Follow-Up 2005-2006

Frequency of Reported Symptoms

Initial symptoms are similar in the case and control populations.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>cases n=190 (%)</th>
<th>controls n=34 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue</td>
<td>175 (92)</td>
<td>30 (88)</td>
</tr>
<tr>
<td>Headache</td>
<td>159 (84)</td>
<td>29 (85)</td>
</tr>
<tr>
<td>Muscle aches</td>
<td>150 (79)</td>
<td>27 (79)</td>
</tr>
<tr>
<td>Muscle weakness</td>
<td>146 (77)</td>
<td>25 (74)</td>
</tr>
<tr>
<td>Fever</td>
<td>149 (78)</td>
<td>26 (76)</td>
</tr>
<tr>
<td>Anorexia</td>
<td>119 (63)</td>
<td>21 (62)</td>
</tr>
<tr>
<td>Rash</td>
<td>101 (53)</td>
<td>9 (26)</td>
</tr>
<tr>
<td>Trouble walking</td>
<td>87 (46)</td>
<td>11 (32)</td>
</tr>
<tr>
<td>Eye pain</td>
<td>91 (48)</td>
<td>15 (44)</td>
</tr>
<tr>
<td>Swollen glands</td>
<td>47 (25)</td>
<td>12 (35)</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>58 (31)</td>
<td>12 (35)</td>
</tr>
<tr>
<td>Sensitivity to light</td>
<td>83 (44)</td>
<td>13 (38)</td>
</tr>
<tr>
<td>Loss of balance</td>
<td>82 (43)</td>
<td>12 (36)</td>
</tr>
</tbody>
</table>
WNF Follow-Up 2005-2006
Initial Results

► Certain measures such as mental health and vitality appear to be decreased in WNV fever patients at 2-3 months post onset when compared to the general population.

► Early data indicates that WNV fever patients show no difference in these scores at the 9 month post infection point when compared to the general population.

► Too early in study to discuss comparison with control population.
Patients with WNV infection (both WNF and WNND) experience long-term morbidity (1 year follow up). Patients with more severe illness did not report more chronic symptoms than patients with milder illness. WNF may not be a self-limited benign illness and may be a subclinical encephalitis. (Carson et al., CID 2006)
Other Recent Outcome Studies

Mental status comparison between WNND and WNF patients 9 months after illness showed greater confusion and difficulty in concentrating in WNND than WNF patients. (Haaland et al EID 2006).
Risk factors for severe disease include increasing age, immunosuppression, diabetes, and possible genetic predisposition.

Most WNF patients recover in first few months. For some, problems may linger (subclinical encephalitis? Other risk factors?).
Treatment
Treatment

Experimental:

► Clinical trial of interferon for meningoencephalitis patients underway based on decreased mortality seen in mice given interferon before WNV infection.

► Ribavarin to inhibit WNV replication.

► I.V. high WNV titered immunoglobulin has reported benefit for WNV encephalitis patients in Israel.

► Role of steroid treatment unknown

► Antisense oligomers that bind to WNV RNA to inhibit translation: phase II (efficacy) trials underway

► Supportive Care
Prevention
Prevention

► Personal Protection
  ▪ Vaccination

► Mosquito Control
WNV Vaccines

- A live, attenuated WNV (veterinary) vaccine
- A formalin-inactivated WNV (veterinary) vaccine
- A “naked” DNA vaccine encoding the prM and E genes
- A live, attenuated dengue serotype 4-WNV chimera
- A live attenuated Yellow Fever-WNV chimera
- A recombinant envelope protein vaccine expressed in *E. coli* or *Drosophila* cells
- A canarypox virus vectored vaccine
- A recombinant vaccine (truncated envelope protein 80E and a non-structural protein - NS1) from the WNV New York Flamingo strain.
...But will people want to be vaccinated?

“Universal vaccination would unlikely result in societal savings unless the incidence of disease increases substantially over what has been seen in the past six years, or the cost of vaccination were <$12.00 per person vaccinated” (Zohrabian et al., EID 2006)
Aerial Pesticide Spraying for WNV Mosquito Control and the Incidence of Respiratory Complaints in Sacramento County, August 2005

Este Geraghty, MD, MS, MPH
University of California Davis
Geraghty Study

► Research Question
  ► Does aerial spraying with a pyrethrin pesticide for West Nile virus mosquito control increase an individual’s risk for a respiratory problem?

► Hypothesis
  ► Aerial spraying does not increase the incidence of respiratory complaints as measured by hospital discharge and emergency room data.
Geraghty Study: Emergency Room Visits

- Medical Information Reporting for California (MIRCal), 01/01/05
  - ED Data
    - Data elements: DOB, service date, principle diagnosis, zip code, disposition, gender, ethnicity, among others
  - Hospital Inpatient Discharges
- Case-crossover design and GIS will be used to evaluate timing of ED-room visits with spray time and location
- Study underway 2006 - 2007
Prevention

Rests with mosquito control and personal protection.
Conclusion

► Public health efforts to understand the dynamics of human disease help focus our prevention efforts
Acknowledgements

► Jamie Riggs-Nagy (VBDS)
► Cynthia Jean (VRDL)
► Ervic Aquino (VBDS)
► Shilpa Gavali (VRDL)
► Many local agencies who have helped out on our follow-up work
Where it all began…

West Nile Region of Uganda

Mt. Luku Island

Murchison Falls

www.game-reserve.com/uganda_murchison_falls.html
www.min.uni-kiel.de/.../ugandaweb/wnile.html