Dynamic drivers of disease emergence in Africa

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Dynamic drivers of disease in Africa

How does changes in land use and anthropogenic changes affect diseases?

And how do we study it?
Case study: Zambia/ Zimbabwe

- Trypanosomiasis/tse-tse
- Land use changes
  - Protected area
  - Area where livestock has been increasing
  - Former large-scale farms with low biodiversity
Case study: Ghana

• Henipa virus/ bats
• Urban –rural migration
• Livelihoods, poverty, ecology and the association with disease
  – How do humans interact with bats and what perceptions do they have of the risks
  – Protected/sacred area
  – Urban area
Case study: Sierra Leone

• Lassa fever/ multimammate rats
• Land use changes and rodent ecology
  – Urban-rural
  – Irrigation and precipitation
  – Human-rat interaction and risk perceptions
Case study: Kenya

- Rift valley fever/ mosquitoes
- Land use changes
  - Protected area vs irrigated area
  - Pastoralist areas
Case study: Kenya

- Socio-economic
- Costs of disease
Case study: Kenya

- Making changes in a highly diverse landscape
- Increased number of scavengers
- Increased numbers of mosquitoes
Case study: Kenya

- Participatory rural appraisals indicated a concern about rodents
Case study: Kenya

• What to study:
  – Can we trust hospital data?
  – Screen all febrile patients
  – Too many differentials: Malaria, RVF, Dengue, YF, Brucella, Leptospira, Chikungunya, CCHF
Case study: Kenya

• Who to study:
  – Humans and livestock
  – Mosquitoes
  – Rodents
  – Ticks?
Salome Bukachi
Institute of Anthropology, Gender and African Studies, University of Nairobi, and
John Muriuki, Damaris Mwololo and Purity Kiunga, College of Agriculture and Veterinary Sciences, University of Nairobi

Ian Njeru and Joan Karanja
Disease Surveillance and Response, Ministry of Health, and
Salome Wanyoike
Department of Veterinary Services, Ministry of Agriculture, Livestock and Fisheries

Rosemary Sang and Joel Lutomiah, Kenya Medical Research Institute

Mohamed Said, Enoch Ontiri, Johanna Lindahl, Shem Kifugo, Fredrick Tom Otieno, Deborah Mbotha and Bernard Bett
International Livestock Research Institute
Cross-cutting issues

- Participatory rural appraisals
- The economic burden of disease
- The association between poverty and zoonoses-the vicious circle
- Climate change and predictive modelling
The perfect model?

Ecosystem health

Animal health

Human health
Far from perfect

- Assessing biodiversity
- Assessing poverty
- Assessing human-animal interactions
- Assessing impact

- Finding mitigations

Elephants or mosquitoes?
Assets or knowledge?
Food or animal contact?
Compared to everything else?
Sampling so far
Human diseases listed

1. Malaria
2. Bilharzia, or schistosomiasis
3. Typhoid
4. Diabetes
5. Cancer
6. Chicken pox
7. HIV/AIDS
8. Tuberculosis
9. Brucellosis
1. CBPP
2. Trypanosomiasis
3. CCPP
4. FMD
5. Helminthosis
6. Mange
7. Orf
8. RVF
9. Anthrax
10. Heart water
11. Orchitis
12. Black water
13. Lumpy skin disease
14. Rinderpest
15. Ticks
Serological survey

- 2,848 animals (599 (21%) cattle, 1383 (49%) goats and 867 (30%) sheep) sampled in Bura and Hola.
- 1,092 human samples collected.
- Blood samples are being collected from patients who visit local hospitals in Bura, Hola, Ijara and Sangailu health centres with current or history of fever over the last 14 days.
Entomological survey

Sampling of adult mosquitoes was done using CDC light traps baited with carbon dioxide.
• Densities of the primary RVF vectors are significantly higher in irrigation fields than in the residential areas; (ii)

• Proportion of the primary RVF vectors in Murukani village, one of the non-irrigated areas, is higher during active irrigation phase compared to non-irrigation phase

• No adults or larvae were trapped or collected in Sangailu, the control site in Ijara, during the period
Mosquitoes reared from larvae

<table>
<thead>
<tr>
<th>Sampling site/Village</th>
<th>Breeding habitat</th>
<th>Species</th>
<th>Number of mosquitoes identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Irrigation Board¹</td>
<td>Unit drain</td>
<td>Aedes mcintoshi</td>
<td>55</td>
</tr>
<tr>
<td>National Irrigation Board¹</td>
<td>Unit feeder</td>
<td>Aedes mcintoshi</td>
<td>105</td>
</tr>
<tr>
<td>Village 1</td>
<td>Unit feeder</td>
<td>Culex univittatus</td>
<td>5</td>
</tr>
<tr>
<td>Village 1</td>
<td>Unit feeder</td>
<td>Culex pipiens</td>
<td>8</td>
</tr>
<tr>
<td>Village 1</td>
<td>Unit feeder</td>
<td>Anopheles gambiae</td>
<td>4</td>
</tr>
<tr>
<td>Village 1</td>
<td>Unit feeder</td>
<td>Culex vansomeri</td>
<td>8</td>
</tr>
<tr>
<td>Village 2</td>
<td>Unit drain</td>
<td>Culex univittatus</td>
<td>31</td>
</tr>
<tr>
<td>Village 2</td>
<td>Unit drain</td>
<td>Uranotaenia spp.</td>
<td>9</td>
</tr>
<tr>
<td>Village 7</td>
<td>Block feeder</td>
<td>Culex univittatus</td>
<td>58</td>
</tr>
<tr>
<td>Village 7</td>
<td>Block feeder</td>
<td>Culex pipiens</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>284</td>
</tr>
</tbody>
</table>

Table 1: Types and number of mosquitoes reared from larvae collected from various irrigation canals in Bura irrigation scheme
¹National irrigation board demonstration fields
Rodent collection
Rodent collection
Activities planned for the next quarter:

• Complete the screening of serum and blood samples from livestock and people
• Commence analyses of samples collected from rats (and a few from bats)
• Finalize sampling that is on-going in the health centers and commence laboratory analysis of the samples collected
• Carry out repeat entomological surveys and commence laboratory analysis of mosquito samples for blood meal sources and infection patterns
• Start a longitudinal entomological and serological survey
Not the end....
....but the beginning

Open to questions
Open to discussion
Agriculture Associated Diseases

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better lives through livestock

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<table>
<thead>
<tr>
<th>Type of wildlife-livestock-human interface</th>
<th>Level of Biodiversity</th>
<th>Characteristics of Livestock Population</th>
<th>Connectedness between populations</th>
<th>Main interface</th>
<th>Examples of zoonotic disease with altered dynamics</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Pristine’ ecosystem with human incursion to harvest wildlife and other resources</td>
<td>High</td>
<td>No livestock</td>
<td>Very low, small populations and limited contact</td>
<td>Ignorable WL interface, large WH interface</td>
<td>Ebola, HIV, SARS, Nipah virus in Bangladesh and India</td>
</tr>
<tr>
<td>Ecotones and fragmentation of natural ecosystems - farming edges, human incursion to harvest natural resources</td>
<td>High but decreasing</td>
<td>Few livestock, multiple species, mostly extensive systems</td>
<td>Increasing contact between people, livestock and wild animals</td>
<td>WH and WL interface dominating, increasing LH</td>
<td>Kyasanur Forest disease, Bat rabies, E. coli interspecies transmission in Uganda, Nipah virus in Malaysia</td>
</tr>
<tr>
<td>Evolving landscape - rapid intensification of agriculture and livestock, alongside extensive and backyard farming</td>
<td>Low, but increasing peri-domestic wildlife</td>
<td>Many, both intensive and genetically homogenous, as well as extensive and genetically diverse</td>
<td>High contacts between intensive and extensive livestock, people and peri-domestic wildlife. Less with endangered wildlife.</td>
<td>Patchwise large LH interface, decreasing WH and WL</td>
<td>Avian influenza, Japanese encephalitis virus in Asia</td>
</tr>
<tr>
<td>Managed landscape - islands of intensive farming, highly regulated. Farm land converted to recreational and conservancy</td>
<td>Low, but increased number of certain peri-domestic wildlife species</td>
<td>Many, mainly intensive, genetically homogeneous, biosecure</td>
<td>Fewer contacts between livestock and people; increasing contacts with wildlife.</td>
<td>Small but increasing WL and WH, decreasing LH</td>
<td>Bat-associated viruses in Australia, WNV in USA, Lyme disease in USA</td>
</tr>
<tr>
<td>Urban landscape- high densities of humans, with peri-urban intense farming and urban lower intense farming, close to people. Habitat fragmentation of wildlife</td>
<td>Low</td>
<td>High value animals, mainly small ruminants or pigs, and poultry in the urban centres</td>
<td>High densities yield high connectedness</td>
<td>Patchwise increasing LH and WH, especially poor areas</td>
<td>Plague outbreaks, Leptospirosis, Dog rabies</td>
</tr>
</tbody>
</table>
## Ecosystem services – and disease emergence

<table>
<thead>
<tr>
<th>Ecosystem service</th>
<th>Importance</th>
<th>Effect of decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provisioning</td>
<td>Economics, livelihoods</td>
<td>Increased poverty</td>
</tr>
<tr>
<td>Regulating</td>
<td>Health, environment</td>
<td>Increased disease</td>
</tr>
<tr>
<td>Cultural</td>
<td>Well-being, recreation</td>
<td>Increased stress?</td>
</tr>
<tr>
<td>Supporting</td>
<td>Basis for the other services</td>
<td>Increase in all above</td>
</tr>
</tbody>
</table>
Hierarchy of needs according to Maslow.
Regulating services

Cultural services

Provisioning services

Health

Infections

Physical and chemical

Stress

Lack of energy
Lack of nutrients
Too much energy

Lack of nutrients
Lack of energy

Nutrition

Land use changes
Biodiversity

Land degradation

Socio-economics

Pollution
Climate

Wildlife

Livestock

Vectors

Biodiversity

Land use changes

Socio-economics

Provisioning services

Health

Physical and chemical
Basic epidemiological principles

- For an outbreak to occur: $R_0 > 1$
- SIR model

Susceptibles ➔ Infectious ➔ Removed

Susceptibles ➔ Exposed ➔ Infectious ➔ Removed
Increased number of susceptible

New population at risk

Close contact between different species

Transfer or recruitment of new vectors

New habits, new cultures

Migration of people or animals to new areas

Increased contact with wildlife

New species at risk / host transfer

Increased number of susceptible

Global trade and travelling

Urbanization

Markets

Close contact with wildlife

Environmental land degradation

Governmental finances and priorities

Undernutrition, starvation

Decreased immunization and immunity

Poverty

Civil unrest

Ageing population

Decreased immunization and immunity

Markets

Urbanization

New habits, new cultures

New species at risk / host transfer

Migration of people or animals to new areas

Global trade and travelling

Increased number of susceptible
Destroyed agricultural land, soil degradation

- War, migration
- Disrupted social systems

- Pollution
- Water scarcity
- Lack of knowledge

- Poverty
- Increased incidence of HIV
- Starvation, malnutrition
- Remote areas
- Lack of fundings

- Excess, incorrect use of antibiotics and antivirals
- Pathogen evolution

- Compromised immune system
- Inadequate health systems
- Resistant pathogens
- Increased infectivity

- Starvation, malnutrition

- Lack of fundings

- Ageing population

- Increased incidence of HIV
Access to medicines → Removed/recovered

Improved nutrition → Immunization programs

Adequate health systems → Global trade

Urbanization → Improved infrastructure

Irrigation

Increased animal production → Education

Improved nutrition

Global trade → Immunization programs

Access to medicines

Removed/recovered
Anthropogenic action: Increased irrigation

Effect on ecosystem: Creates more larval habitats

Possible consequence: More infected vectors

Epidemiologic consequence: More individuals exposed

Increased disease

• This step requires the presence of a vector-borne pathogen and the presence of competent vectors
Deforestation

- Decreased biodiversity
  - Increased disease transmission (where biodiversity would cause a dilution effect)
    - Example: Some vector-borne diseases, such as Lyme disease
  - Reduced disease transmission (where biodiversity would cause an amplification effect)
    - Example: Parasites in greater apes which are favoured by host richness

- Changed vector habitats
  - Increased vector populations
    - Example: Deforestation give more agricultural land, more irrigation and more Japanese encephalitis virus increase
  - Decreased vector populations
    - Example: Malaria decrease after deforestation in Thailand

- Habitat fragmentation
  - Increased edge effects and interfaces between humans, domestic animals and wildlife
  - Increased animal densities and contact rates
    - Example: Habitat destruction and forest encroachment were drivers between Nipah virus outbreaks
  - Increased animal densities and contact rates
    - Example: Increased parasite burdens in wildlife
One action - multiple results

Agricultural industrialization

- Improved veterinary care
  - Increase use of antibiotics
  - Eradication of animal diseases
    - Eradication of rinderpest - better cattle production
    - Eradication of Salmonella pullorum - better poultry production but increased Salmonella enterica
    - Decrease of bacterial diseases in animals
    - Increase risk of drug resistant pathogens

- Intensification
  - Higher animal densities
    - High propagation of infectious diseases, such as avian influenza
  - Higher biosecurity
    - Decreased risk of introduction of disease

- Extensification
  - Trends of ecologic production with outdoor animals
  - Backyard poultry
  - Low biosecurity and low animal density
  - More natural behaviour could give less stress and increase animal welfare
  - Increased infectious diseases such as Toxoplasma gondii