Disease mapping in Public Health: from theory to practice?

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How to use risk maps

- What can be mapped?
- What do PH services require maps of?
- What is a Risk Map?
- Three steps:  
  i) calculation of a risk map  
  ii) presentation of a risk map  
  iii) communication of risk; to individuals, populations, health services.
- Problems of uncertainty of predictions (false diagnosis).
- What we might learn from risk maps (driving factors/variables etc..., aetiologies)
Why communicate risk?

• Better preparedness of PH services (doing your job better; but nobody notices if you do it badly)
• Better PR for PH services (good idea; but you don’t get fired for not using risk maps)
• Opportunity costs of risk mapping (what else could be done with the same resources? e.g. the clinic’s roof is leaking, etc.). PH service costs and benefits
• Opportunity liabilities (what happens if nothing is done to communicate risk? PH high treatment costs, plus e.g. arthritic complications – sequelaes of flavivirus infections). Societal costs and benefits.
Global Warming Studies and Predictions....
How NOT to communicate risk.....
What is a Risk Map?

• A Risk Map predicts areas at risk of harbouring an insect/tick or other vector, or the diseases these vectors transmit
• Risk Maps may also be used to predict non-vector borne diseases (if environmentally determined)
• A Risk Map is usually on a scale of 0 to 1.0 where values $\geq 0.5$ indicate risk
• Risk Maps are probabilistic and define only the similarity of each area to areas known to harbour the vector or disease elsewhere (hence are like diagnoses!).
• There are many different ways (algorithms) for deriving Risk Maps, mostly statistical (few biological)
• Early Warning Systems predict risk at some future point in time (and space), and require quite different modelling approaches (time series or biological)
John Snow and the Broad St. pump, 1854.
The first use of predictive Risk Maps.

Figure 2. Replica of the Broad Street pump and John Snow pub (background), London.

Figure 4. Cholera outbreak in Golden Square, Broad Street, London, 1854. The pump handle was removed when the epidemic was waning and appears to have had no effect, although the Reverend Henry Whitehead, who produced these figures, thought that the closure of the pump may have prevented recurrence of the epidemic.
Examples of risk maps

1. West Nile Virus in the USA
West Nile Virus Transmission Cycle

Mosquito vector

Incidental infections

West Nile virus

Bird reservoir hosts

Incidental infections
West Nile Virus risk mapping: the emerging situation

1. 1999. WNV first reported in New York, in August. 62 clinical human cases, 7 deaths (all >67 yrs). Serosurvey in Queens suggested many sub-clinical cases.

2. 2000. WNV seropositive birds recorded from 12 states in the NE USA, in an area 10 times larger than in 1999.

3. 2001. Further expansion of range southwards (Florida, Georgia) and westwards.

4. 2002. WNV spreads to more than 40 states. > 4000 human cases and 284 deaths.

Examples of regularly updated CDC maps of the distribution of WNV positive birds (above, in green) and mosquitoes (below, in red) (nationalatlas.gov in 2000, cindi.cdc.gov from 2001 onwards).
The Spread (and numbers) of Human West Nile Virus cases in the USA 1999 to 2006

Human cases are the darker colors
Landsat data (here for New York) have lots of spatial, but no temporal information
Meteorological satellite data (here for the UK) have lots of temporal, but little spatial information.

Risk maps can combine the two sorts of satellite data.
Is a WNV risk map for birds (reservoir hosts) a guide to risk to humans?

Green = Risk Map
for 0, 1, 2 etc WNV-infected birds, derived from environmental satellite data.
Red = 1, 2, 3 etc. human cases of WNV
WNV Risk Maps were distributed as full resolution .pdf files.
Constructing human risk maps for West Nile Virus in the USA

Landsat TM image processed to highlight urban/rural differences (5, 4, 3 in RGB)
WNV-infected bird risk map (green) on Landsat image – a guide to individual human risk
Human population density by zip5 region (brown) on Landsat image
Human population by zip5*Infected bird risk = population-weighted WNV Risk Map, i.e. a guide to human population risk (of more relevance to PH services)
Seasonal Model of WNV-infected birds
Examples of risk maps

2. The leishmaniasis in the Middle East
New Risk maps for old diseases

Cutaneous Leishmaniasis

Visceral Leishmaniasis

Probability of suitability
Examples of risk maps

3. Tick-borne encephalitis (TBE) in Europe
Risk map for recent TBE in Sweden

in collaboration with Gert Olsson and Swedish PH services
Satellite-derived predicted distribution of Tick-Borne Encephalitis compared with established foci (mapped 1997)
Switzerland

New foci since 2000 (www.bag.admin.ch)

76% of new foci within 1 pixel (8 km) of “false positive” predictions

Data and analysis EDEN TBD

Randolph SE (2000), Advances in Parasitology 47, 217-243
Network of independent but synergistic biological and non-biological factors contributing to the recent increase of TBE in Eastern Europe. Examples of data from Estonia, Latvia, Lithuania.
“We do these things not because they are easy, but because they are hard.”

President J.F. Kennedy, on committing the USA to landing a man on the moon before the end of the 1960s.
The Future?

Albrecht Durer. The Revelation of St. John: the four riders of the Apocalypse. 1497/98

Conquest
War
Famine
Death/Disease
Chikungunya in La Réunion

Total cases in La Réunion (dots, right hand scale) and cases imported into mainland France (histogram, left hand scale) in 2005 and 2006.

...and imported back into France

Aedes albopictus

Confirmed presence of Aedes albopictus
Swings (and Roundabouts)?

AS MARQUETING REQUESTED IT

AS SALES ORDERED IT

AS ENGINEERING DESIGNED IT

AS WE MANUFACTURED IT

AS FIELD SERVICE INSTALLED IT

WHAT THE USER WANTED
Disease mapping in Public Health: from theory to practice?

Important questions (EDENext et al)

What are the important infectious diseases (prevalence, incidence, PH costs)?
Do these have environmental and other links?
What datasets exist for these diseases; spatial and temporal?
Can they be (anonymised and) shared with the modellers?
Do PH services need and/or want Risk Map predictions?
What sort of Risk Maps are required (spatial/temporal)?
How would they improve PH services?
How should Risk Maps be presented, explained and communicated to users (PH services, clinicians, general public)?
Who else to involve (economists, sociologists, anthropologists, affected groups)?
How to begin collaboration?
Aedes albopictus - the Asian Tiger Mosquito
Lessons from Chikungunya in La Réunion

Diseases without Frontiers. The global spread of infectious diseases
Why do we need Models?

We never have enough data of the right sort (where? when? how much disease?)

<table>
<thead>
<tr>
<th>Space</th>
<th>Poor</th>
<th>Rich</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global malaria</td>
<td>Japanese encephalitis</td>
<td>Asian Tiger mosquito</td>
</tr>
<tr>
<td>Japanese encephalitis</td>
<td>Hantavirus</td>
<td>Cholera</td>
</tr>
<tr>
<td>Hantavirus</td>
<td>Presence/absence</td>
<td>Tsetse</td>
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<tr>
<td>Presence/absence</td>
<td>Suitability</td>
<td>Variation through time</td>
</tr>
<tr>
<td>Malaria, East Africa</td>
<td>Bluetongue, Europe</td>
<td>Dengue, SE Asia</td>
</tr>
<tr>
<td>Rich</td>
<td>OW screwworm, Iraq</td>
<td>West Nile Virus, USA</td>
</tr>
<tr>
<td>Presence/absence</td>
<td>Abundance</td>
<td>Presence/absence</td>
</tr>
</tbody>
</table>

Models increase the spatial and temporal resolution of disease risk
Culex pipiens - vector of West Nile Virus (WNV)
Network of independent but synergistic biological and non-biological factors
Examples of data from Estonia, Latvia, Lithuania.

Sociological Change
- Economic changes
- Climate Change
  - Sudden increase in Spring temperature
  - Global brightening ??

Economic changes
- Higher unemployment
- More wealth & leisure

Increased Disease Incidence
- Increased co-feeding transmission of TBEV
- More hosts for adult ticks

Agricultural Change
- Decline of agriculture
  - More hosts for adult ticks
  - Increase in rodents (transmission hosts)

Human behaviour
- Environmental awareness?
  - Environmental change

Environmental Change
- Regeneration of shrubs
- Increase in rodent populations?
  - (transmission hosts)

Vector Behaviour
- Increased co-feeding transmission of TBEV

Vector Abundance
- More ticks

Host abundance
- More hosts for adult ticks

Data and analysis EDEN TBD
Sumilo et al, PLoS ONE 2007, 6, e500