Risk mapping and surveillance

Methods and their applications

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Risk mapping and surveillance: Methods and their applications

- Vector-based approach
- Surveillance Objectives
- Keys in a vector-based surveillance system
A vector-based approach

Reservoirs → Vectors → Hosts → Pathogens → Reservoirs

Environment
A vector-based approach

- Identification
  - Presence/Absence
  - Quantification
  - Dynamics

- Climate
  - Ecosystem
  - Landscape
  - Evolution

- Evolution

- Presence/Absence
  - (H-V-R-E)

- Identification
  - Susceptibility
  - Capacity

- Identification
  - Infection
  - Syndrome
  - Serology

- Capacity

- Identification

- Identification

- Identification

- Identification

- Identification

- Identification
Surveillance Objectives

- **Vigilance**
  - Detection of an outbreak caused by a new vector borne disease in a country
    - RVF in southern France
  - Detection of a novel serotype of a known disease
    - The case of BTV-8 in northern Europe (Netherlands)
  - Risk prediction of a new outbreak of a known or unknown disease

- **Surveillance**
  - Efficiency of implemented control methods
    - BTV8 and BTV1 in France
  - Epidemiological changes
    - West Nile in the Camargue zone
    - RVF in East Africa
A vector-based surveillance system
Hosts

- Quantification

- Detection of the aetiologic agent
  - Clinical/syndromic surveillance
  - Sero- Surveillance (longitudinal, case-study surveys)
  - Virus Surveillance

- Resistance/ Susceptibility

1. RVF in Comoros, Mayotte, 2009
2. RVF in Senegal, 1998
3. WN in southern France, 2000
Outbreaks in 2006-2007

Movements

- Officially
- Uncontrolled
First reported case: Child, 12 years old, September 2007, Comoros
Retrospective survey on 250 dengue-like syndromes in humans has confirmed the existence of 10 RVF cases (Sissoko et al., 2009)

3 different studies following the human case (Comoros)

1. Studies focused in M’Tsangamougi area – March 2008 and animals from illegal movements

2. Retrospective study on bovine sera from 2007 and 2008

3. Development of a serosurveillance network based on sentinel herds (goats) to follow up the virus circulation
1. **Studies focused in M’Tsangamougi area – March 2008 and illegally imported goats (2/2) - April 2008**

   - 13 animals IgG+ and 3 IgM+ among 79 zebus tested
   - Follow-up of bovines found seronegative in March 2008

   **One seroconversion** has been observed among the 18 seronegative bovines

   - Follow-up of one caprine farm (9 seropositives among 12 tested goats) and 4 other bovine farms (16 found + among 53 bovines)
   - Among 29 illegally imported animals, 4 were IgG+ and 2 IgM+

**In conclusion,**

- among the 79 tested zebus, 13 were seropositive in April 2008
- among the 29 illegally imported goats, 4 positive IgG and 2 with IgM (14%)

**Recent circulation of the virus**
2. Retrospective study on bovine sera from 2007 and 2008

Material

• Sera from zebu stored in the veterinary laboratory from 2007-2008
• Random sampling
• Sampling performed between June 2007 and May 2008

Results

• 304 animals were tested in 104 different farms

• Distribution in 14 villages
  ⇒ Virus Circulation all over the island
  ⇒ Importation from neighbouring and suspected islands
Results

• 32 positives meaning 11% of SP (IC: 7-14)

• Distribution:
  ✓ In 7 of the 14 tested villages
  ✓ In 24 farms

⇒ Circulation of the virus in the whole island
Figure 2: Rift Valley fever in Mayotte. a. human cases and animal and herd seroprevalences, b. status of herds sampled for the longitudinal serological study
3. Definition of sentinel herds (goats) to follow up the virus circulation

- 13 caprine farms under investigation
  - Between 4 and 35 animals (mean : 21)
- 272 samples have been analysed

Only, 5 farms were found seronegative and therefore followed up as sentinel herds

- Herds Seroprevalence: 62 % (IC : 35% - 88 %)
- Intra-herd Seroprevalence between 6 and 42 %

⇒ 5 goats herds (between 4 and 35 goats) kept as sentinels
⇒ Sampled every 6 to 8 weeks
RVF Information in Senegal

Diagram showing the flow of information from farmers, through field veterinary surveillance, to district and region levels, and finally to a server and data base, with interactions also involving a veterinary laboratory.
Real-time Access to the data

Partners

Toulouse

Lotus Notes

Field

Dakar

Validation

Pasteur Institute, Dakar

ISRA, Dakar

IRD, Dakar

INRA

CIRAD

ENVL
The case of West Nile: Detection of the pathogen

West Nile evolutive cycle
(Zeller et al., 2001)
West-Nile serologic surveillance, 2000

1 Point = 1 séropositif
1 Point = 1 séronégatif
1 Point = 1 cas clinique
West-Nile clinical surveillance, 2000

Nb of confirmed equine cases

- Fever : 47 (62%)
- Ataxia : 55 (72%)
- Paresis/paralysis: 36 (47%)
- Others :25 (33%)
  - Tremors:7; Hyperesthésiae 6; Chewing: 3
  - Behavioural pb: 2;  Hepatitis: 1
Distribution of the 428 IgG positive equines
IgM levels: Crucial in terms of early detection

Distribution of the 177 IgM positive equines
Early detection

- The information regarding the suspected case is sent via a GSM- Real-time process
- Access to the information via a Website and Emails
- One third of the suspected case were detected through this network
Système d'Information Maladies des Equidés

Page de connexion

Utilisateur :  
Mot de passe :  
valider
Ce site permet de consulter les fiches de recueil clinique ayant été envoyées au serveur par un dispositif portable. Son contenu est accessible à travers le menu ci-dessus, dont voici les items :

- **Accueil** : affiche cette page d'accueil.
- **Fiches** : affiche la liste de fiches de recueil clinique.
- **Historique** : affiche des statistiques concernant la réception des fiches de recueil clinique sur le serveur.
- **Test** : affiche la liste de fiches de recueil clinique de test.

- **Nouvelle fiche** : permet la saisie et l'enregistrement d'une nouvelle fiche de recueil clinique.

- **Déconecter** : ferme la session utilisateur et réaffiche la page de login (il est important de cliquer sur ce lien avant de quitter le site pour que d'éventuelles mises à jour soient sauvegardées).

©Tous droits réservés - Calystene Informatique Santé - 2004
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## Système d'Information Maladies des Equidés

**historique des fiches reçues**

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Host susceptibility

- BTV, Host susceptibility to the vector: Bovines > Ovines > Caprins (Viennet et al. 2012)
- West-Nile, Host susceptibility to the disease: Old persons and children > others
Conclusions – Hosts-

- A oriented surveillance, when the hosts are easy to identify
- Early warning system even if it is late compared to the vector part
A vector-based approach

The case of Culicoides into mainland France
Identification of the vectors involved in BTV transmission

Ceratopogonidae, haematophagous
More than 1253 species
About 40 involved in Orbivirus transmission

imicola Complex
Obsoletus Group
Pulicaris Group

Morphological identification
Type of traps
Entomological surveillance, Culicoides, France, 2002-2006
2003-2004: Settlement of C. imicola in southern France

Mai 2003
1 mâle
sur 2218 Culicoides

sept 2003
1 femelle gravide
sur 38 Culicoides

juin 2004 : 1 femelle sur 8 Culicoides
sept 2004: 1 femelle sur 2 Culicoides
oct 2004: 3 femelles sur 6 Culicoides
BTV DATA BASE for BTV surveillance

**Data**
- Traps data
- Results
- Detailed Identification

**Internet Page**
- Page « site de piégeage »
- Page « campagne de piégeage »
- Page « identification »

**DataBase**
- Table traps
- Localisation Environment
- Date, time Climate Presence of animals
- Table identification
- Species name Number
- Table maps
- species distribution maps
- Data on the disease
- Disease surveillance Information Booklet

**Technician DDSV**
- Entomologist
- Epidemiologist
- Farmers
- Veterinarians
- Vet services

**Maps**
- Table maps

**Others**
- Page « Monography »
- Page « bulletins »
Les bulletins

Régulièrement des bulletins pour faire le point sur la maladie et sa progression sont édités.

Afin de les consulter, cliquez sur le mensuel qui vous intéresse dans le tableau ci-dessous.

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<td>Novembre</td>
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### Déterminations :

- **Campagne**: 2BPL6-4
- **Date de la détermination**: 
- **Espèce**: achrays
- **Estimation**: 
- **Type de détermination**: Estimatif

#### Identification of single species per campaign

#### Ajouter cette espèce dans la détermination

### Récapitulatif pour une campagne :

- **Campagne**: 2BPL4-2

#### Data about species for the whole campaign

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Consultation

Afin d’obtenir la liste des campagnes effectuées pour un site, cliquez sur la commune de votre choix.

La liste des campagnes apparaît alors dans le tableau ci-contre.

Afin de connaître le détail des espèces trouvées pour une campagne, cliquez sur son identifiant dans le tableau.

Les résultats s’affichent dans une nouvelle fenêtre.
Consultation

Afin d’obtenir la liste des campagnes effectuées pour un site, cliquez sur la commune de votre choix.

La liste des campagnes apparaît alors dans le tableau ci-contre.

Afin de connaître le détail des espèces trouvées pour une campagne, cliquez sur son identifiant dans le tableau.

Les résultats s’affichent dans une nouvelle fenêtre.
Commune: PORTO VECCHIO

Latitude: CONFIDENTIEL
Longitude: CONFIDENTIEL
Elevage: Ovins

Environnement du site: Prairie bordée d'une rivière. Piège placé contre la bergerie

Heure début de piégeage: 19:00:00
Température: 13.0000
Métabolisme: Temps calme et dégagé

Heure de fin de piégeage: 08:45:00
Température: 16.0000
Métabolisme: Temps calme et dégagé

Ésence d'animaux: oui

Observations complémentaires:

Détermination estimée

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Détermination définitive

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Vector competence
Finances (Surveillance, Research)
Identification
Presence/Absence
Evolution

Pathogens

① BTV in Europe
② RVF in Mayotte
BTV in Europe: more than 26 serotypes
Identification of new pathogens transmitted by *Culicoides*

- New BTV serotype = new disease?
- Target animals: ovines, but BTV8 in bovines
- BTV6 in Netherlands announced October 24, 2008
  - 3 days later: vaccine serotype
- TOV in Switzerland
  - Toggenburg orbivirus announced Promed November 2, 2008
  - No clinics
- Schmallenberg virus in Germany with congenital malformation, December 2011
Phylogenetic relationships to help in the identification of the introduction process of the disease

Chevalier et al., 2004

Schoemaker et al., 2002

Figure: Phylogenetic relationships of the S, M, and L RNA segments of Rift Valley fever viruses. Maximum Likelihood analysis of the nucleotide (nt) sequence differences among a 561 nt region of S RNA segment (Panel A), a 756 nt region of the M RNA segment (Panel B), and a 176 nt region of the L RNA segment (Panel C) of RVF viruses was performed by using PAUP4.0b10 (Sinauer Associates Inc., Sunderland, MA).
Where to look for the pathogen?

Importance for updated diagnostic tools

- In the Hosts
  - The most common and easiest

- In the Vectors
  - Hard
  - Frustrating, low significance

- Reservoir
  - Important to better understand the disease epidemiology

Important to work in close collaboration with the National and International Reference Laboratories with updated diagnostic techniques with a short delay in terms of response
Reservoirs

Identification
Presence/Absence
Quantification
Dynamics

Case of WN in France
Pathogen detection in the reservoirs

West Nile evolutive cycle
(Zeller et al., 2001)
Reservoirs surveillance, West-Nile in USA
How to survey wild life fauna

**Passive Surveillance**
Via the analysis of dead animals

**Active Surveillance**
Via surveys targeted on hunted animals

Network SAGIR, WNF ➔ Alert

Specific surveillance contingency plans ➔ Diseases with zoonotic and economic impact
West-Nile fever in avifauna, 2004

http://west-nile.cirad.fr
Sero-Surveillance on sentinel birds

4 controls, 6 weeks apart on 150 ducks and 150 domestic chickens (anatidae et gallinacae)
Duck drawing

Photo Jennifer Pradel
Surveillance de la fièvre de West Nile en France

Bienvenue - Gestion des données

L'accès à la base de données ( saisie des informations, correction et administration) est réservé aux partenaires du système de surveillance.

Pour accéder à la base, entrez vos login et mot de passe :

Login [Field] Mot de passe [Field]

[Connexion]
Surveillance de la fièvre de West Nile en France

Interrogations - Choix de la requête

Code du site sélectionné :

1321 - Croazier

Nombre de prélèvements : 63
Nombre de positifs : 19

Détails :
- Liste des prélèvements effectués
- Liste des oiseaux positifs

Vous pouvez choisir un autre site en cliquant sur la carte ci-contre.

Attention
Positivité ne signifie pas séroconversion. Une séroconversion est avérée uniquement si un oiseau positif a été trouvé négatif précédemment.
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<td>négatif</td>
</tr>
<tr>
<td>2004-10-07</td>
<td>1321J</td>
<td>positif</td>
</tr>
</tbody>
</table>
Surveillance de la fièvre de West Nile en France

Résultat de la requête
"Tous les oiseaux positifs du site 1321 - Croazier"

<table>
<thead>
<tr>
<th>Code de l'oiseau</th>
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<tr>
<td>1321B</td>
</tr>
<tr>
<td>1321J</td>
</tr>
<tr>
<td>1321JJ</td>
</tr>
<tr>
<td>1321R</td>
</tr>
<tr>
<td>1321RB</td>
</tr>
<tr>
<td>1321RR</td>
</tr>
<tr>
<td>1321VB</td>
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<tr>
<td>1321VJ</td>
</tr>
<tr>
<td>1321VV</td>
</tr>
</tbody>
</table>

Afin de connaître le commémoratif d'un oiseau trouvé positif, veuillez cliquez sur son code dans le tableau ci-dessus.

<table>
<thead>
<tr>
<th>Commémoratif de l'oiseau :</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date du prélèvement</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
Afin de connaître le commémoratif d'un oiseau trouvé positif, veuillez cliquer sur son code dans le tableau ci-dessus.

**Commémoreatif de l'oiseau : 1321VJ**

<table>
<thead>
<tr>
<th>Date du prélèvement</th>
<th>Code du prélèvement</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004-06-04</td>
<td>003346-12</td>
<td>négatif</td>
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<td>2004-07-20</td>
<td>003347-7</td>
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<td>2004-09-09</td>
<td>003379-1</td>
<td>positif conféré</td>
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<td>003383-12</td>
<td>positif</td>
</tr>
<tr>
<td>2020-06-04</td>
<td>003386/11</td>
<td>douteux, à recontrôler</td>
</tr>
</tbody>
</table>
What to conclude on the Reservoir component?

• (Bird) Sentinel Surveillance is not any more appropriate, to hard to manage, and does not avoid or predict outbreaks

• Need of adapted diagnostic tools (bird serology)

• Early warning remains a key point with a rapid lab diagnosis as well as a realtime data management system
Environnement: integrated approach

Climate Ecosystem Landscape Evolution

① Case of BTV in France
The case of BTV and *Culicoides*

- Maximum Activity around +24 °C
- Fly stop around: +15-18 °C
- Can resist to short periods at -1.5°C
- Max temperature mean > +12.5°C (10 following days > 13°C)

Population dynamics: Presence of *Culicoides* linked to humidity and inversely correlated with heavy rainfalls and wind
- in dry zones: after rainfalls
- in temperate zones: at the end of the hot season
Clinical signs
Serological proved
Suspected presence

BTV distribution, 1991

Atlas des maladies infectieuses des ruminants, 1991
P.C. Lefèvre, IEMVT/CTA
Vector survival

> 12°5 all over the year

> 12°5 for 7 months

Mellor, 2002

Purse, 2005
Risk mapping

- Identification
  - Presence/Absence
  - Quantification
  - Dynamics

- Climate
  - Ecosystem
  - Landscape
  - Evolution

- Evolution
- Identification
  - Presence/Absence

- Identification
  - Presence/Absence
- (H-V-R-E)
- Evolution

- Quantification
  - Infection
  - Syndrome
  - Serology
  - Susceptibility

- Identification
  - Presence/Absence
- Quantification
- Dynamics
- Competence
Establishment risk for emerging vector-borne infection: a case study of canine leishmaniasis in southern France

Figure 1. Schematic overview of the approach.
doi:10.1371/journal.pone.0082371.g001

Hartemink et al., 2012
Transmission pathway and risk factors involved in dengue fever outbreaks

Racloz et al., 2012
Typical timescale for the host and vector are distinct leading to asymptotic dynamics:

- SIR model for the host with a modified incidence rate (vectors disappearing from the model)
- SI model for the vectors with the hosts disappearing from the model

**TABLE 1.** Description of parameters meaning in the compartmental model depicted in Figure 1
Infected Zone

Free Zone

Analysis of the risk of introduction

Customs

Zone at risk

Identification of the favorable ecosystem
Introduction
Infected Zone

Free Zone

Zone at risk

Introduction

Prevalence

Detection level

Contingence Plan

Cross-sectional study n°1
Prevalence

Detection level

Cross-sectional study n°1

Cross-sectional study n°2

Infected Zone

Free Zone

Zone at risk

Introduction
Infected Zone
Free Zone
Zone at risk

Introduction

Prevalence

Detection level

Contingence Plan
Emergency Vaccination

Cross-sectional study n°1
Cross-sectional study n°2

time
Introduction

Zone infectée

Zone indemne

Zone à risque

Start of the epidemics detected by the passive surveillance

Prevalence

Detection level

Cross-sectional study n°1

Cross-sectional study n°2

time
Introduction

Prevalence

Epidemics with severe human case

Epizootics start detected by the passive surveillance

Detection limit

Cross-sectional study n°1

Cross-sectional study n°2

Infected Zone

Free Zone

Zone at risk
Why tick diseases do increase in the United States?

Time for surveillance and time for research
Special Thanks to

Pascal Hendrikx
Renaud Lancelot and Eric Cardinale
Michèle Bouloy
Following the BTV-2 outbreak in Corsica in 2000, surveillance has been implemented in Mainland southern France in 2001.