Impact of vector and host distribution on the processes of introduction, amplification and emergence of a multi-host infectious disease:

An integrative ecological and landscape study on West Nile virus in southern France

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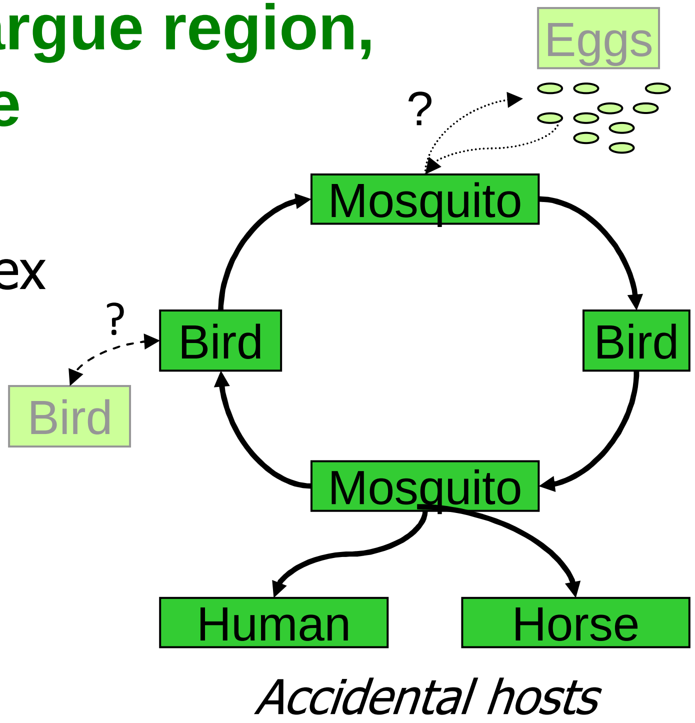
West Nile Virus in the Camargue region, Southern France

- *WNV:* flavivirus
- *WNF:* an emerging arbovirosis with a complex epidemiological cycle:
  - Birds
  - Mosquitoes (mainly *Culex* genus)
  - Horse and man: accidental hosts

➡ A multi-host disease



- Emergence in the Camargue region
  - Recurring outbreaks (2000, 2004)
- Low level virus circulation in wild birds
  - Overall seroprevalence < 1%

(Balança et al., 2009)

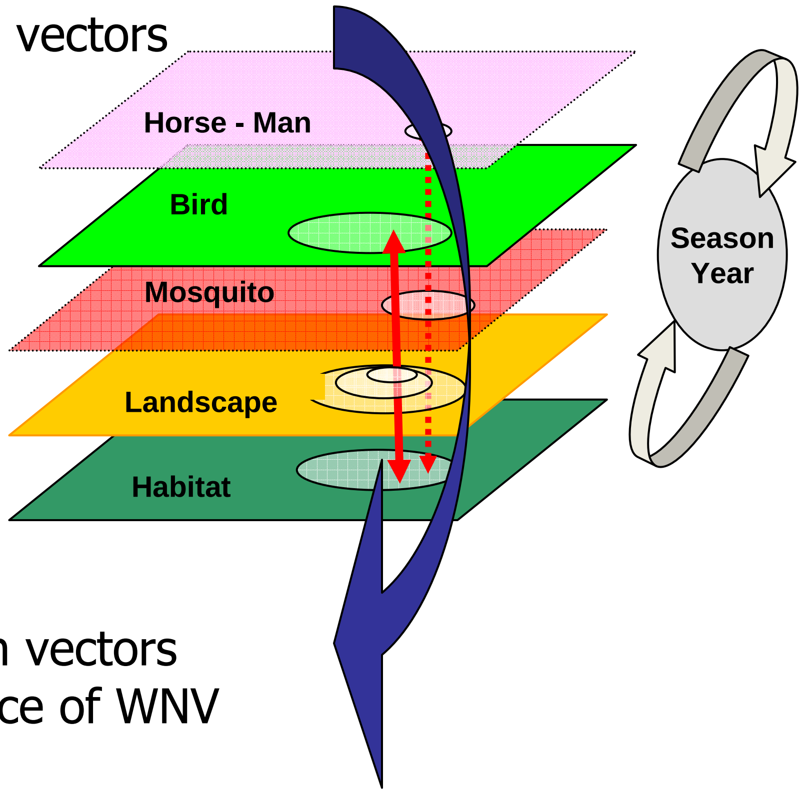
A lot of questions

- Which are the vectors?
  - *Culex modestus* or/and *Culex pipiens* **(Balenghien, 2008)**
- Which are the reservoirs?
  - Magpies and sparrows only **(Jourdain, 2007)**
  - All species are able to transmit the virus **(Jourdain, 2008)**
  - Some species have a higher receptivity/competence
- The transmission stops in winter…how to explain WNV persistence?
  - Virus overwintering
  - WNV is chronically reintroduced by migrating birds **(Hubalek, 1999)**
- Does the reservoir host community composition affect WNV transmission?
  - Dilution effect? **(Ezenwa, 2006)**

Ecological and landscape approach

- Study area: Camargue region, France
- A large diversity of potential reservoirs and vectors
- Diversity structured by :
  - a temporal component
  - a spatial component

➡ a wide range in the types of association between reservoirs and vectors



- **Hypothesis**:

Some associations in time and space between vectors and reservoirs are favourable to the occurrence of WNV

Identification of **specific environmental configurations** favourable to introduction / amplification and emergence of WNV

Method

1. Map the seasonal distribution of mosquito and bird populations
   - Expert-based knowledge
   - Geographic Information Systems
   - Field validation
2. Building of risk maps corresponding to different hypotheses
   - Identification of introduction and amplification areas
   - Combination of the different steps -> a scenario
3. Compare model outputs of each scenario with results of seroprevalence studies
   - Ouput: a risk index
   - Regression model: prevalence ~ risk_index
   - Use of Akaike information criterion to compare the resulting models and groups of models

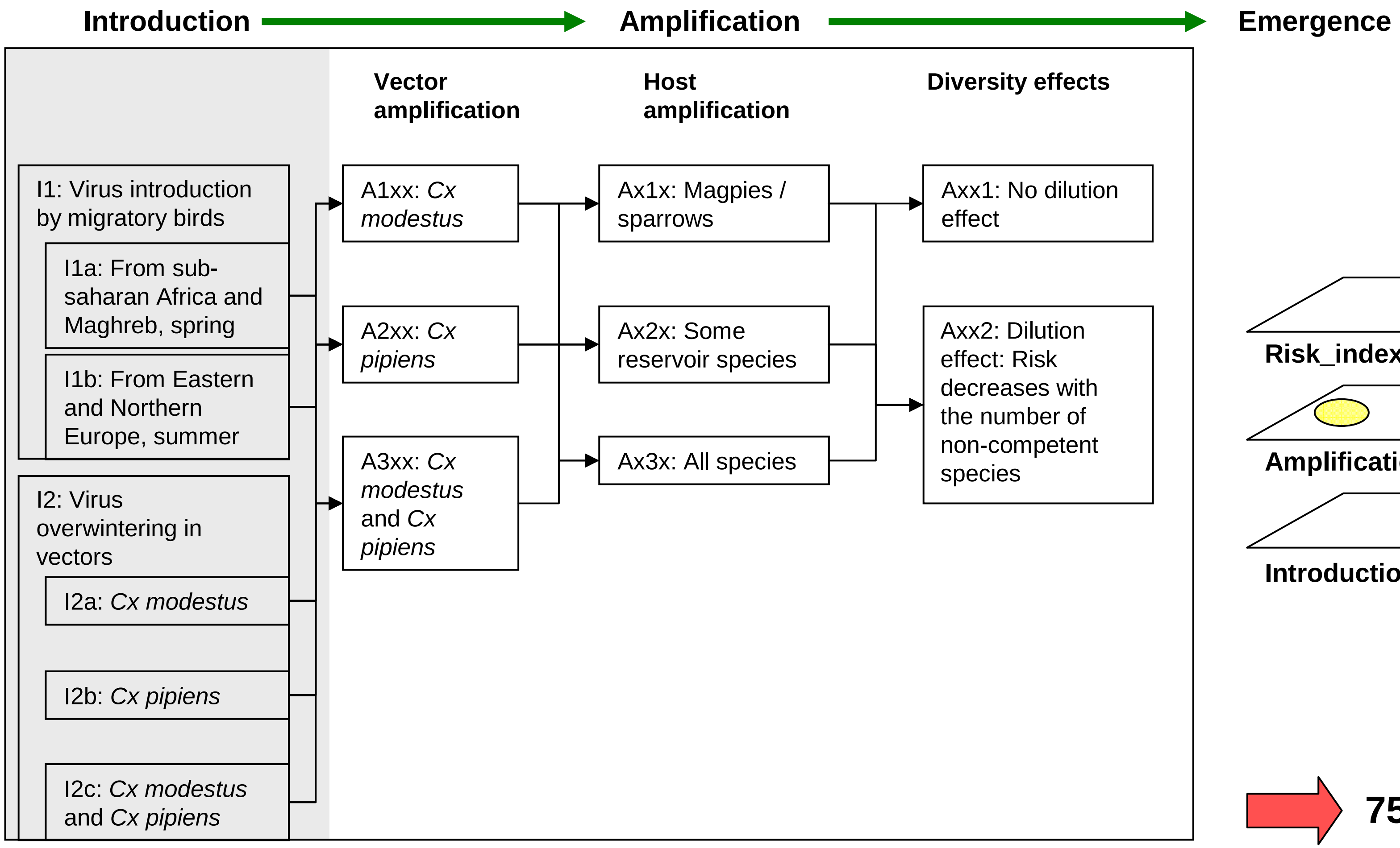
1. Map the seasonal distribution of mosquito and bird populations

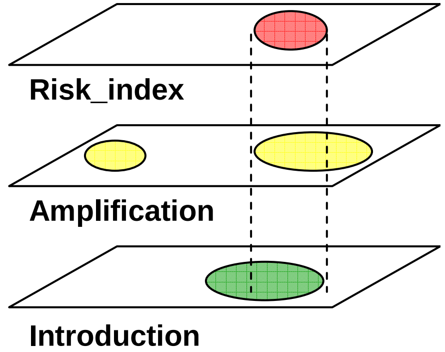
- Ecological map
  - Common typology birds / mosquitoes
  - Landsat ETM+ images

- Bird database
  - 180 species
  - 4 seasons
  - Definition of a probability occurrence index for each ecological unit and each season
  - Migration
  - Spread
  - Reservoir index

Code	Probability of occurrence	Definition
0	absent	Never or accidentally observed at a site
1	uncommon	Observed every year, but with only few observations per year
2	frequent	Observed frequently at a site, but not at every visit
3	common	1 to 10 individual observed at a site during a visit

2. Building of risk maps corresponding to different hypotheses





75 scenarios

3. Compare model outputs of each scenario with results of seroprevalence studies

- Serological survey (2004-2007) on black-billed magpies (*Pica pica*)
  (Balança, 2009; Jourdain, 2007)

- For each scenario:
  - Regression model: seroprevalence ~ risk_index

- Akaike information criterion (AIC) to compare the models
  (Δi=AICi-AICmin)

- Weighted AIC (wAIC) to compare different groups of models:
  - Introduction 1a, 1b, 2a, 2b, 2c
  - Vector amplification 1, 2, 3
  - Host amplification 1, 2, 3
  - Diversity effects 1, 2

(Burham & Anderson, 2004)

Results (1)

- Heterogeneous spatial patterns
- All scenarios outputs (risk indices) are positively correlated with prevalence
- Considering the $\Delta_i = AIC_i - AIC_{min}$:
  - 3 models have substantial support ($\Delta_i \leq 2$)
  - 3 models have slightly less support ($2 < \Delta_i \leq 4$)
  - 25 models have considerably less support ($4 < \Delta_i \leq 7$)
  - 44 models can be considered as having no support ($\Delta_i > 7$)

Example of « best » risk map of WNV in the Camargue area

Introduction

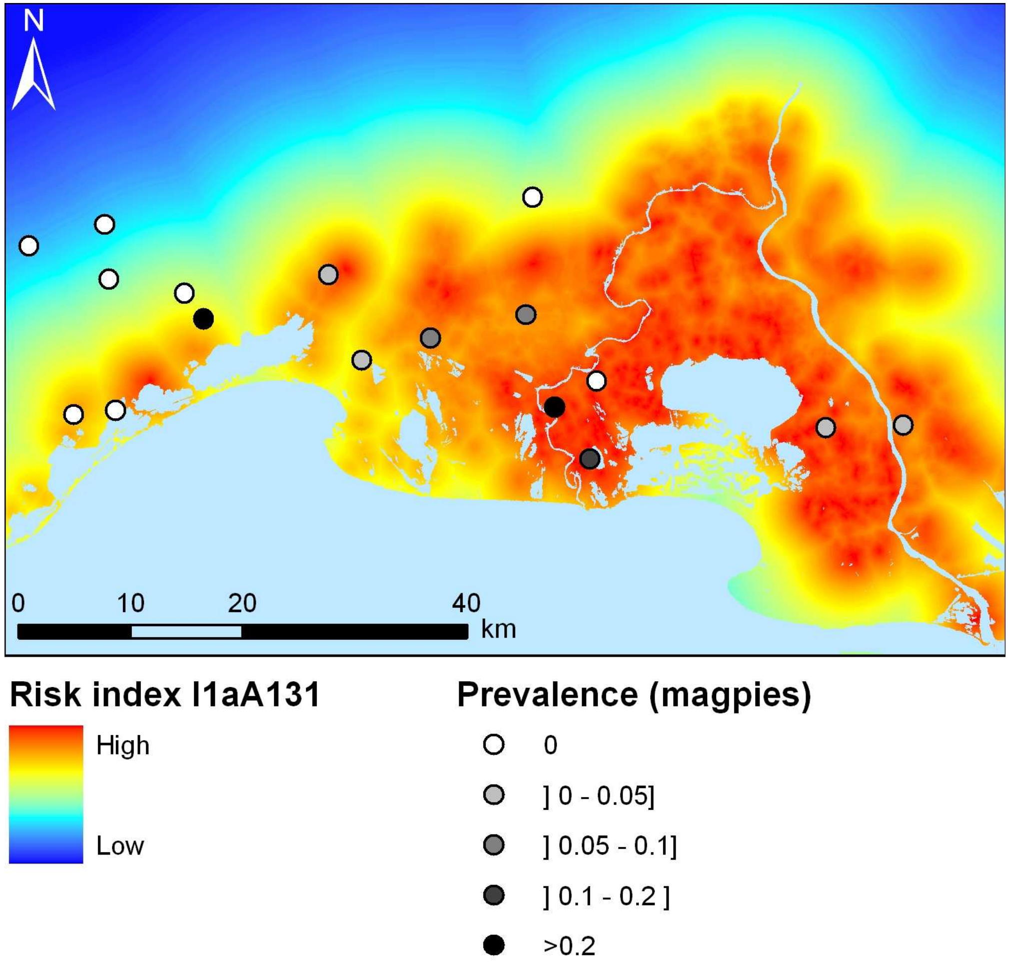
By migratory birds from sub-saharan Africa and Maghreb

Amplification

By *Culex modestus*

By all reservoir species

(no dilution effect)



Results (2)

- Introduction
  - By migratory birds
- Vector amplification
  - *Culex modestus*
- Reservoir amplification
  - Magpies and sparrows are not the only reservoirs
- Dilution effect
  - No

Scenario		ΣwAIC
Introduction by migratory birds	**From Sub-saharan Africa and Maghreb**	**0.221**
	From Eastern and Northern Europe	**0.553**
Virus overwintering	*Culex modestus*	0.090
	Culex pipiens	0.066
	Both species	0.070
Vector amplification	***Culex modestus***	**0.499**
	Culex pipiens	0.131
	Both species	**0.370**
Reservoir amplification	Magpies and sparrows	0.095
	Some competent species	**0.344**
	All species	**0.561**
Diversity effects	**No dilution effect**	**0.773**
	Dilution effect	0.227

Discussion and perspectives

- Multi-host diseases: difficult to study!
- First integrative ecological and landscape study of WNV in France
- Contribute to a better understanding of WNV circulation in Southern France
  - Some hypotheses relative to WNV epidemiological cycle may be rejected in the Camargue context
  - Role of migratory birds also demonstrated by recent studies (Durand, 2010)
- Production of risk maps which match observed seroprevalence patterns
  - *Tool for surveillance / studies*
- Towards dynamic modelling approaches (ABM) (Roche, 2008)
- Comparison with other wetlands areas

Thank you for your attention!