



Transmission du virus du Nil occidental et biodiversité d'hôtes

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<http://www.futureearth.org>





Déclaration d'intérêts de 2014 à 2017


- Intérêts financiers : **aucun**
- Liens durables ou permanents : **aucun**
- Interventions ponctuelles : **aucune**
- Intérêts indirects : **aucun**

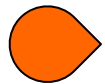


Déclaration de liens d'intérêt avec les industries de santé en rapport avec le thème de la présentation (loi du 04/03/2002) :

Intervenant : Guégan Jean-François

Titre : Transmission du virus du Nil occidental et biodiversité d'hôtes

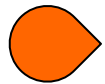
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Consultant ou membre d'un conseil scientifique

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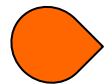
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Conférencier ou auteur/rédacteur rémunéré d'articles ou documents

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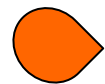
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Prise en charge de frais de voyage, d'hébergement ou d'inscription à des congrès ou autres manifestations

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NON



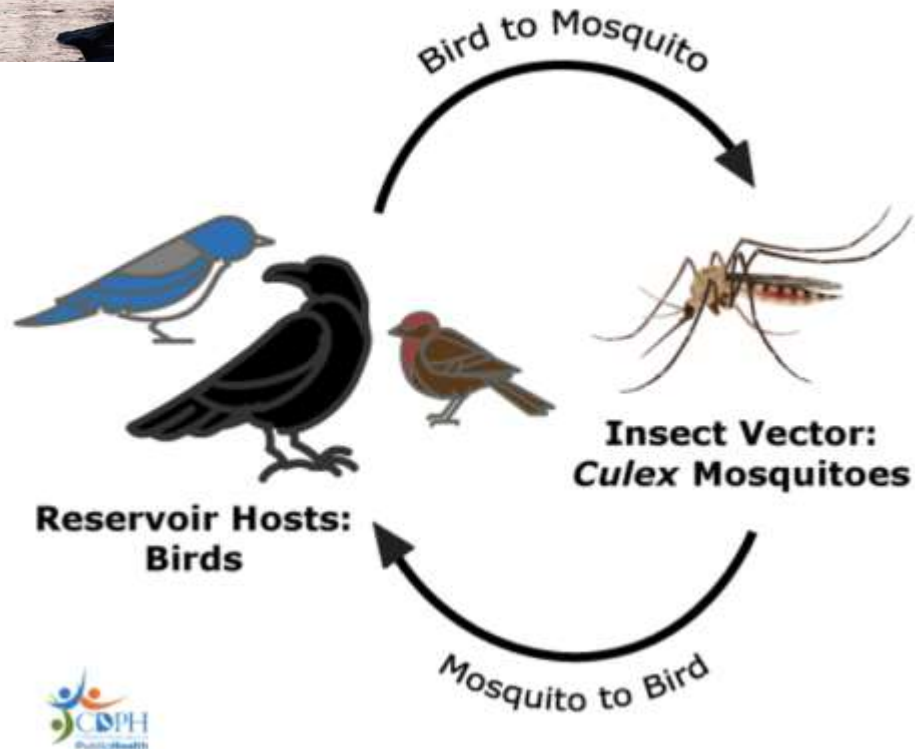
Investigateur principal d'une recherche ou d'une étude clinique

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NON



West Nile Virus Transmission Cycle

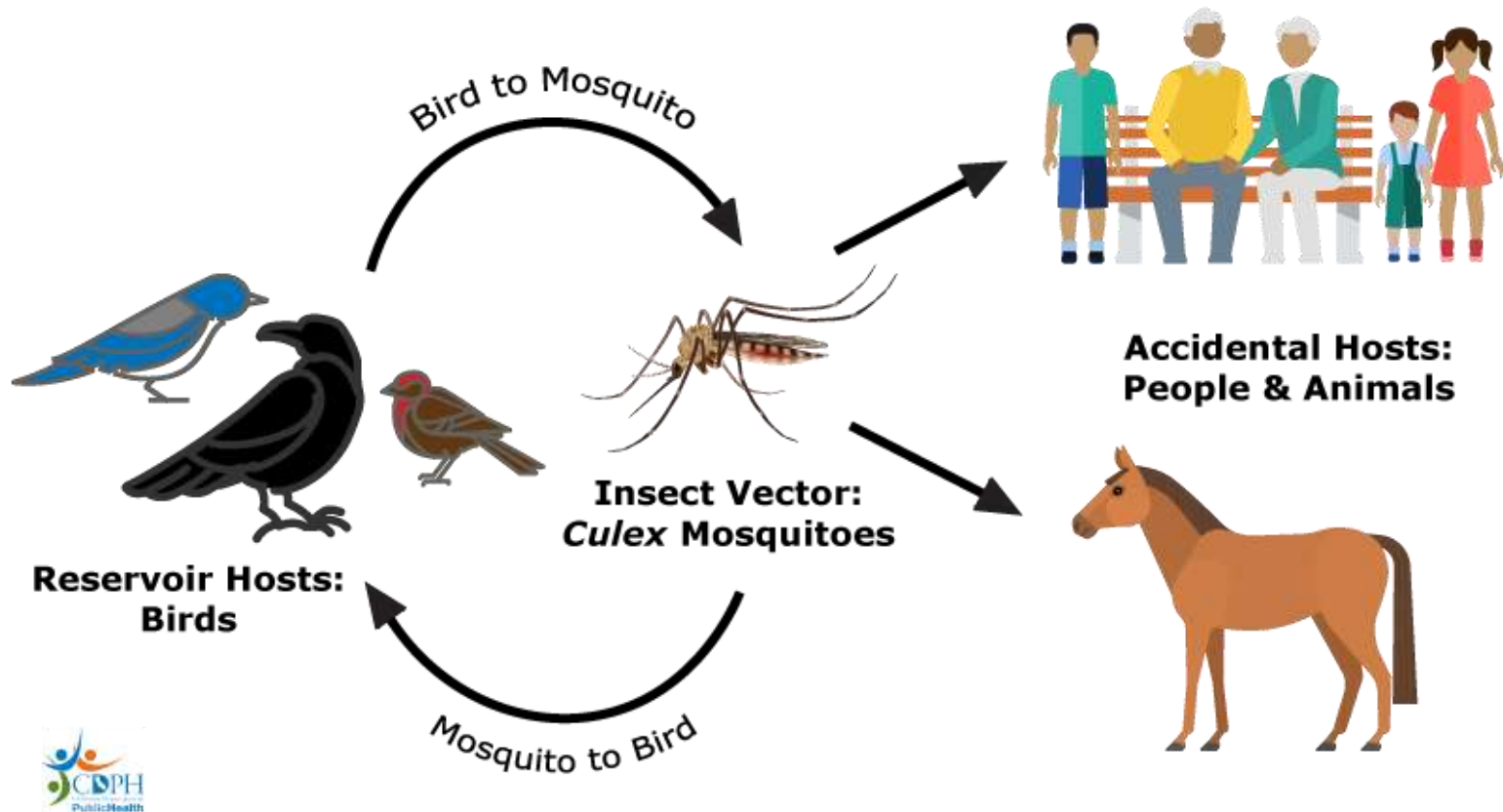


Cycle enzootique



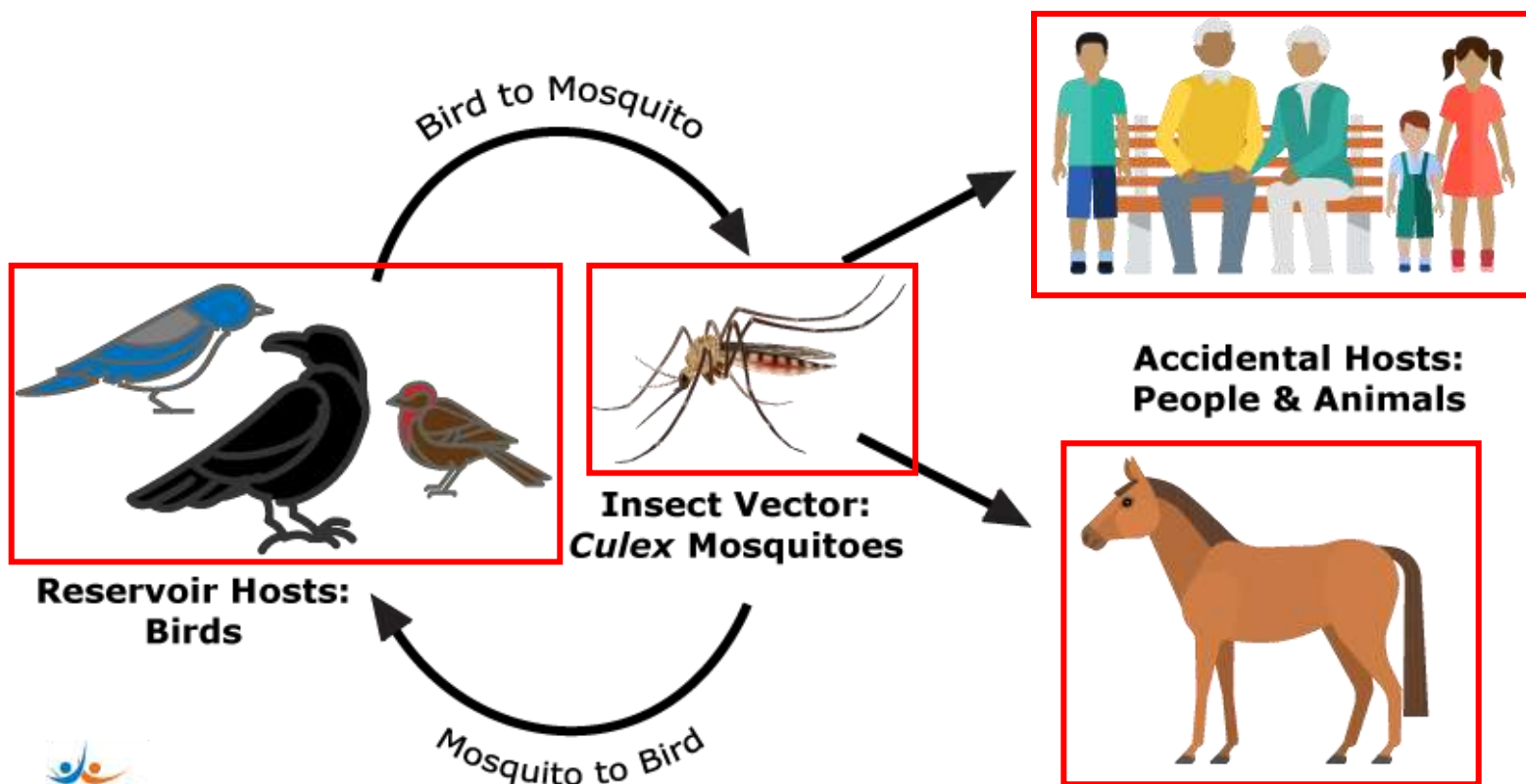
Cycle épidémique

West Nile Virus Transmission Cycle

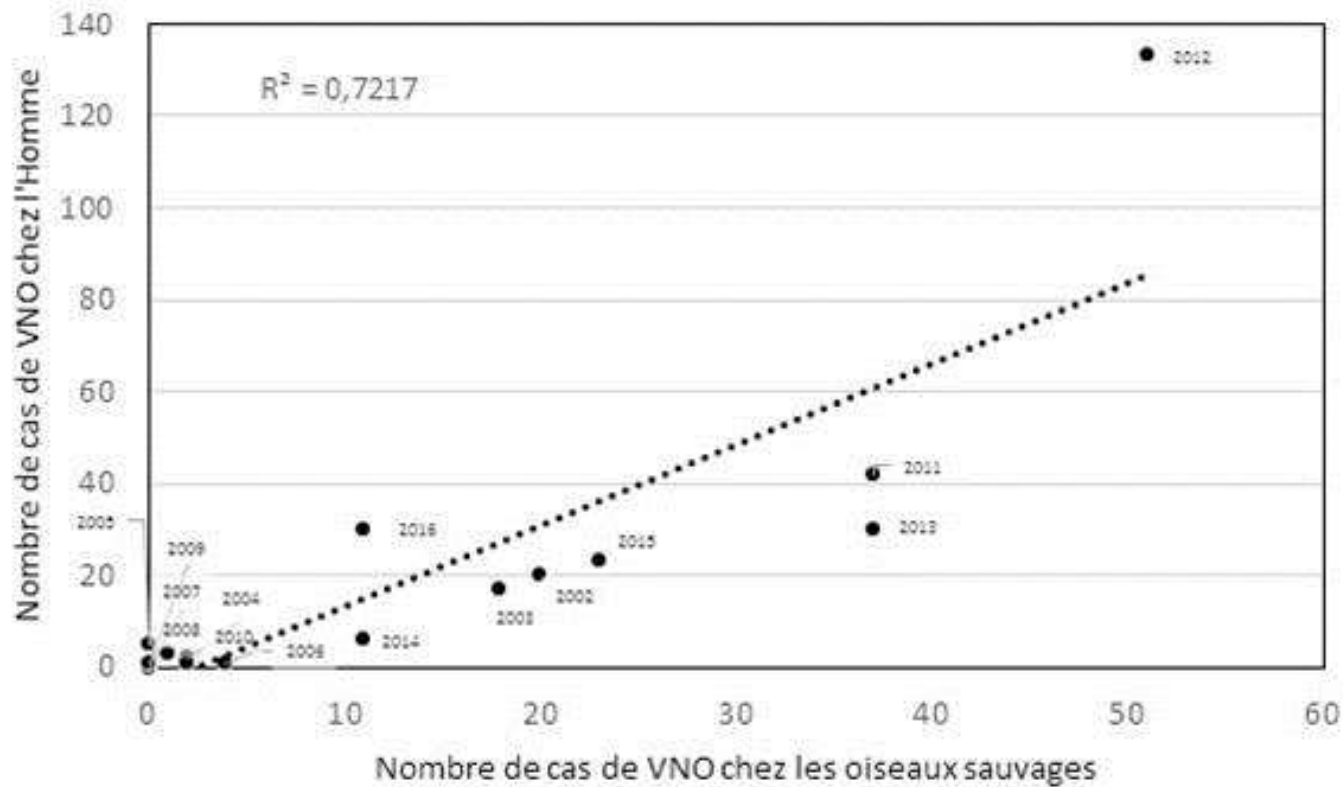


Transmission accidentelle à l'humain et au cheval

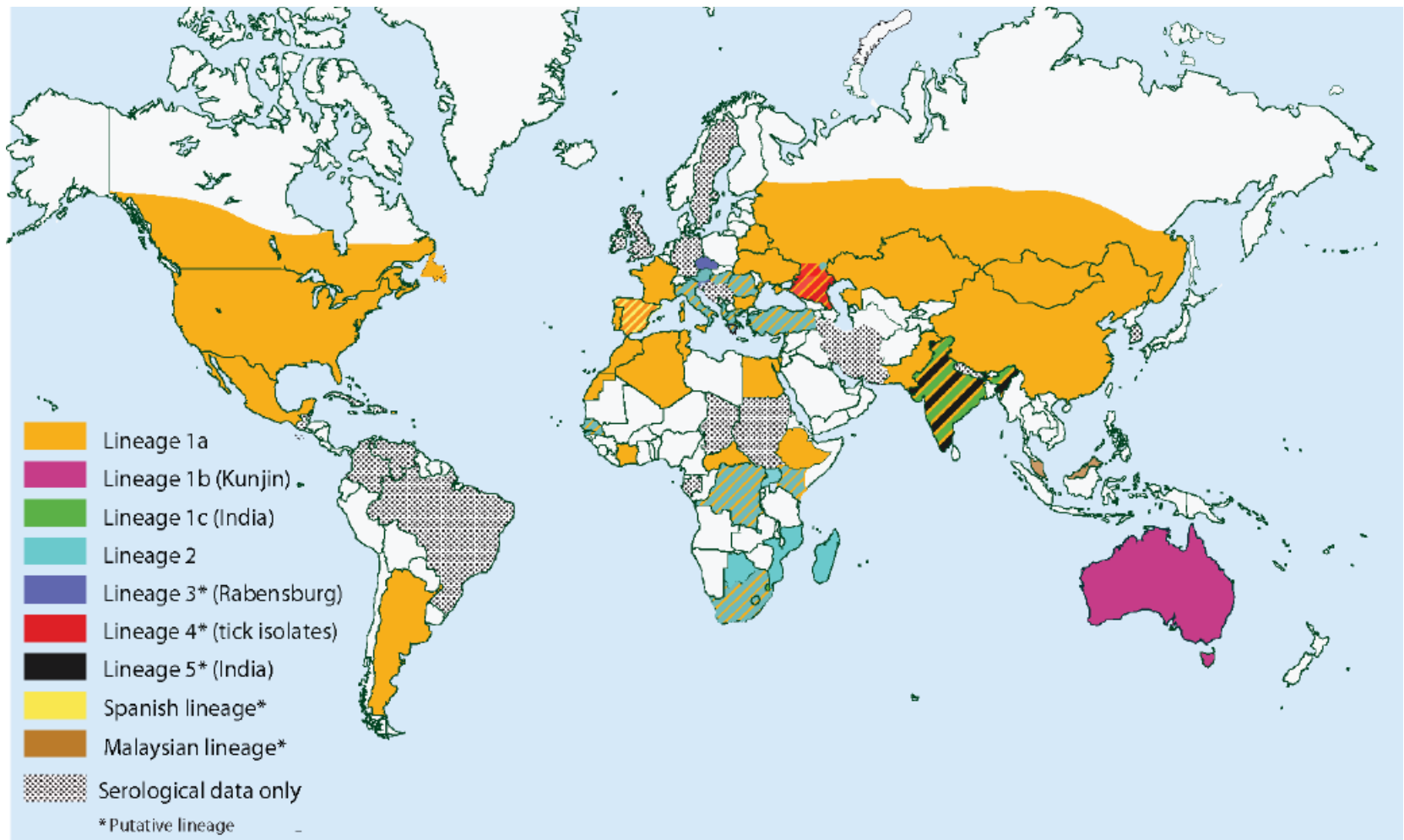
West Nile Virus Transmission Cycle



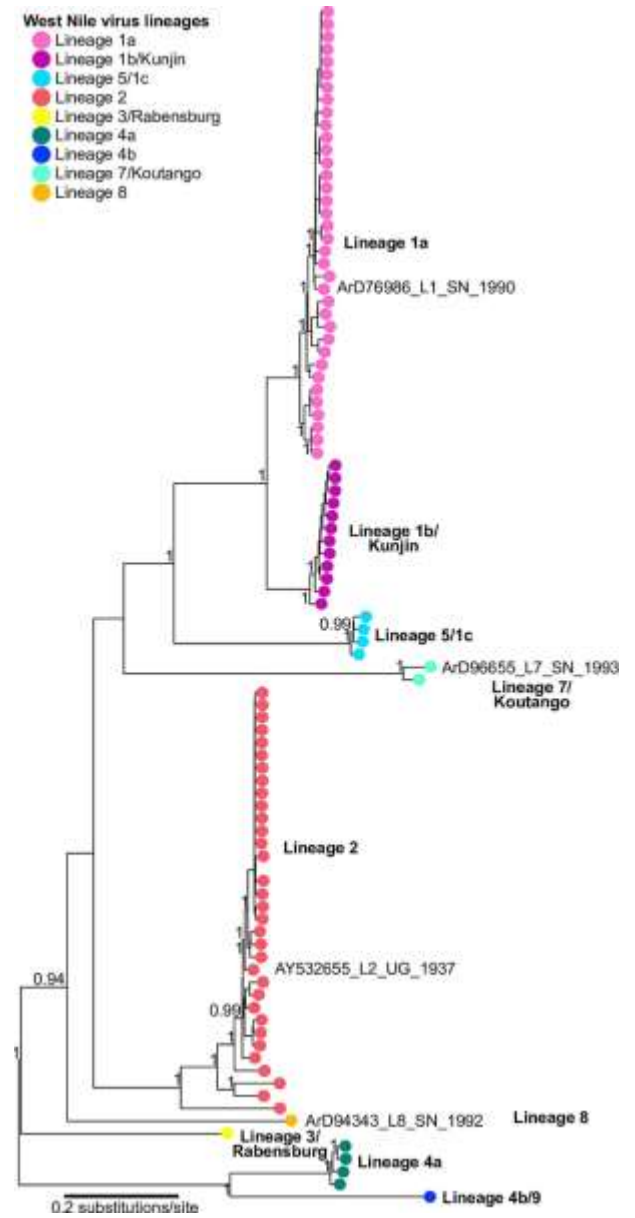
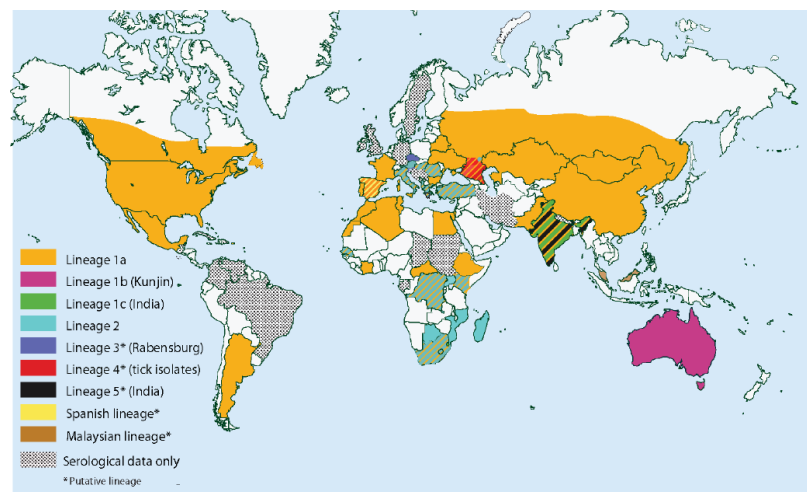
Surveillance intégrée du virus du Nil occidental



Distribution mondiale du virus du Nil occidental

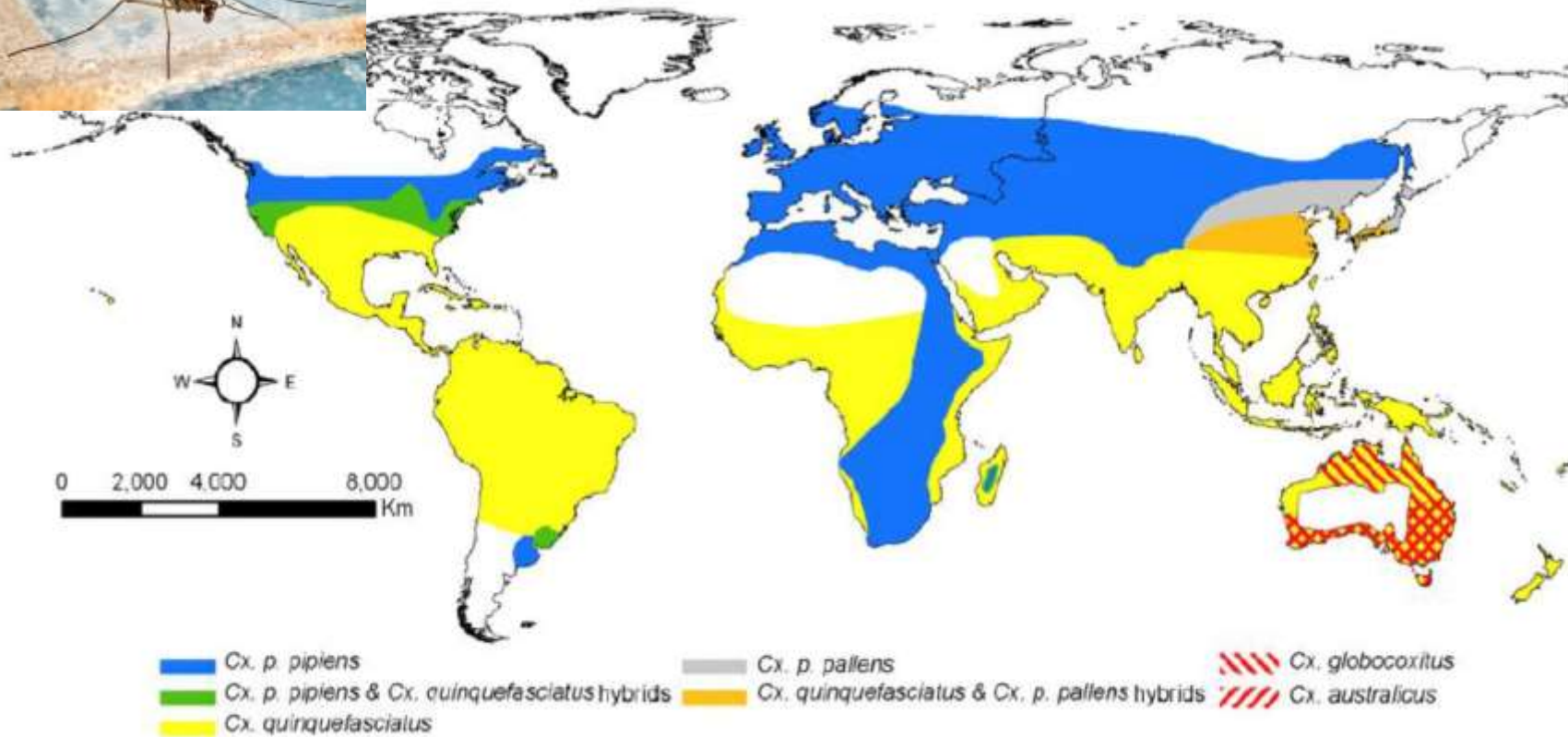


Distribution mondiale du virus du Nil occidental



Fall *et al.* (2017)

Distribution mondiale des insectes du genre *Culex* complexe *pipiens*

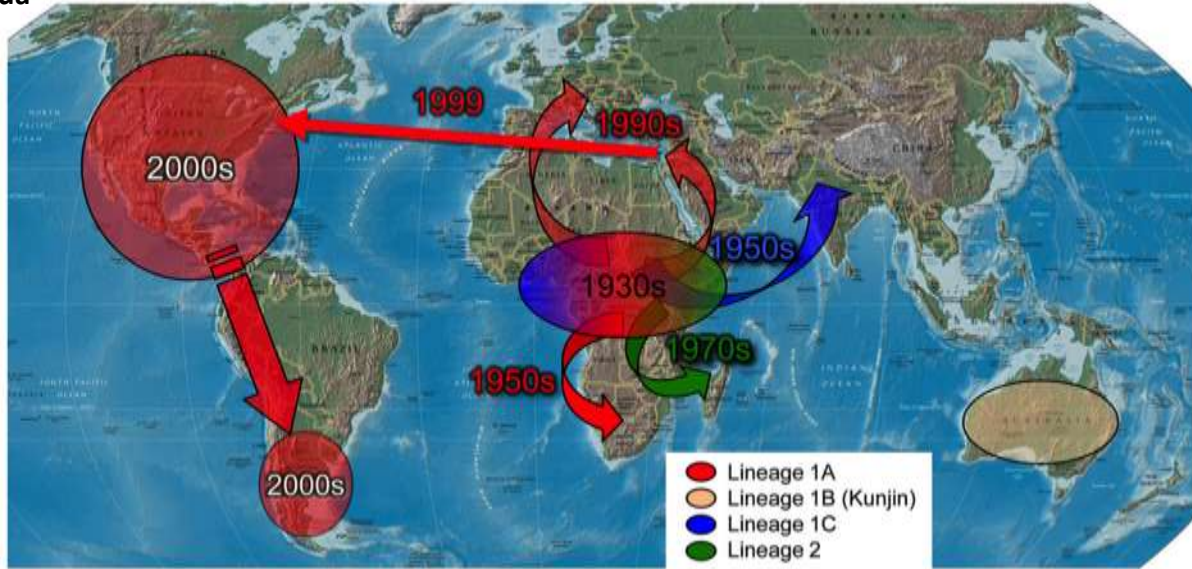


Ciota and Kramer (2013)

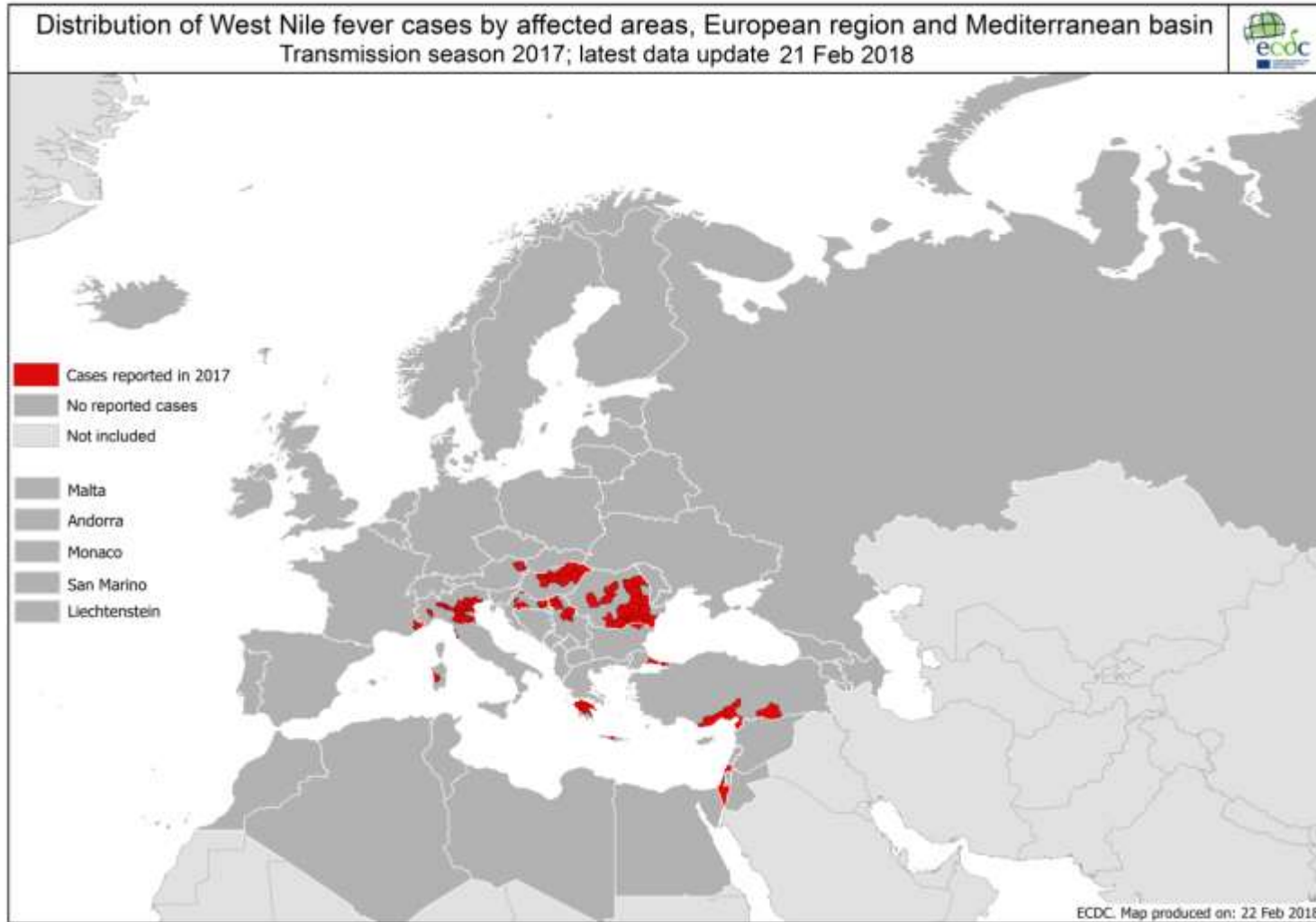
Premiers cas d'infection (connus) par virus du Nil occidental et dispersion spatiale



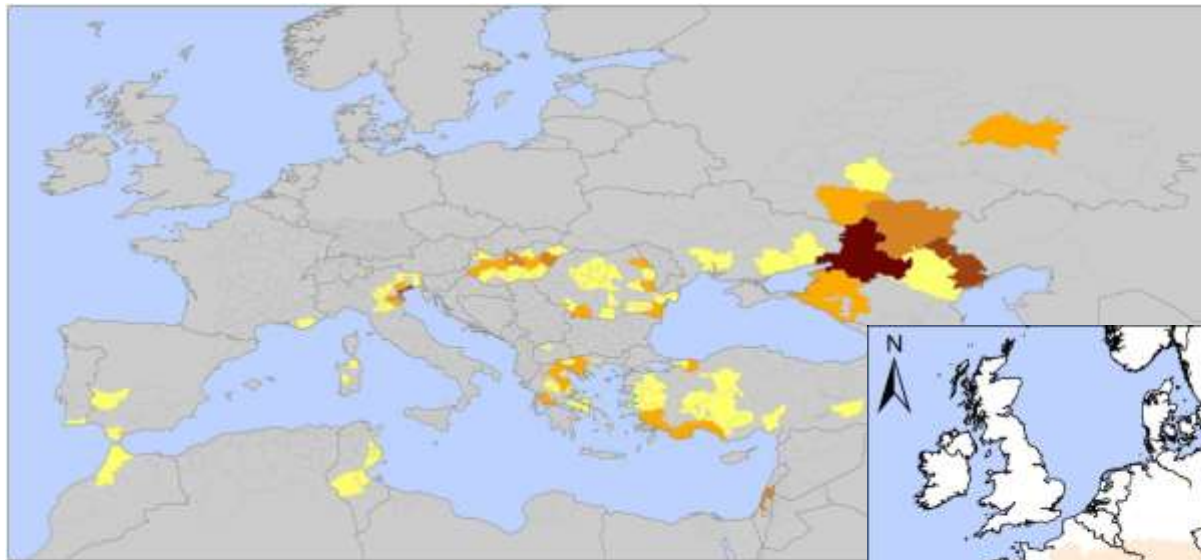
1937 : virus isolé dans le district West Nile, Ouganda



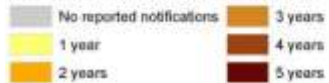
La situation en Europe



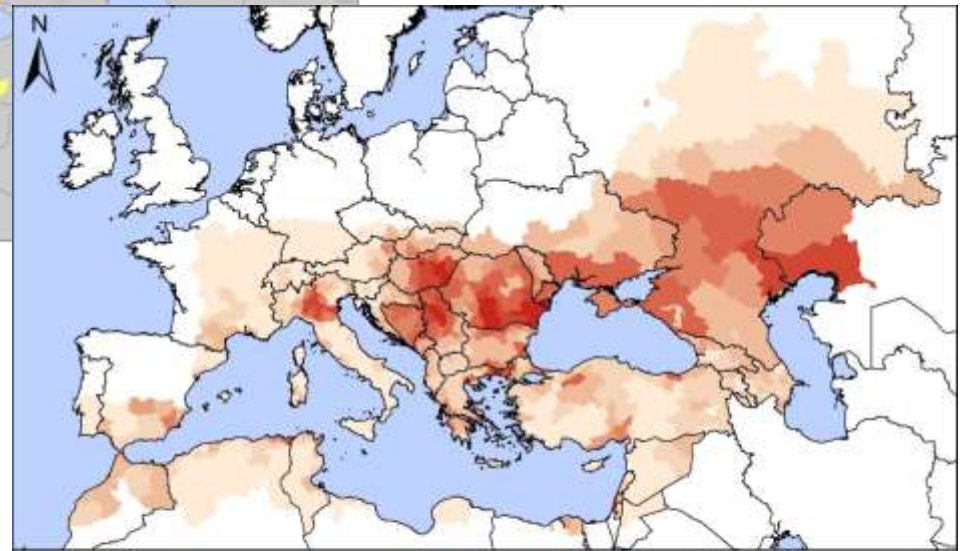
La situation en Europe



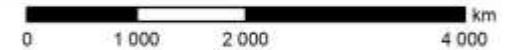
Number of years of WNV reported notifications by district



Tran *et al.* (2014)
sur la période 2002-2011



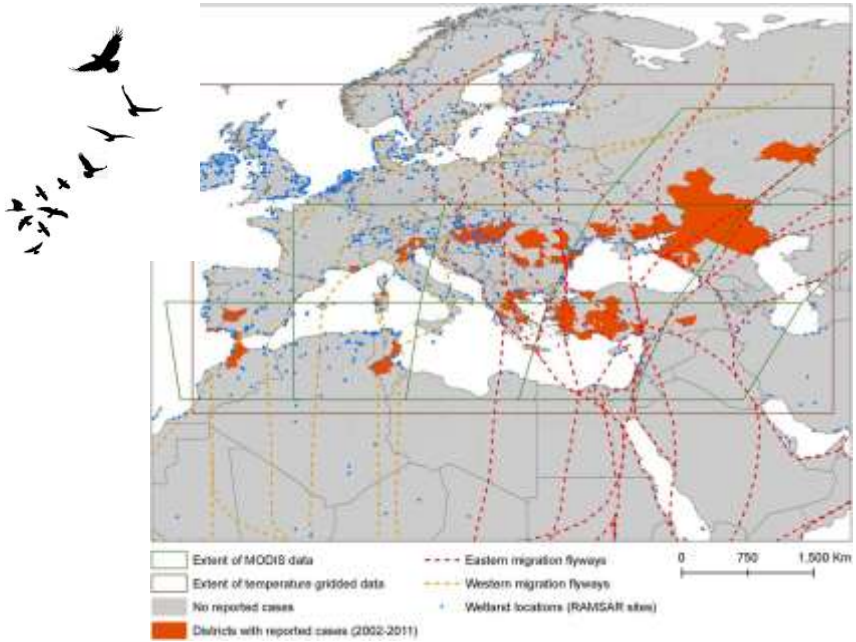
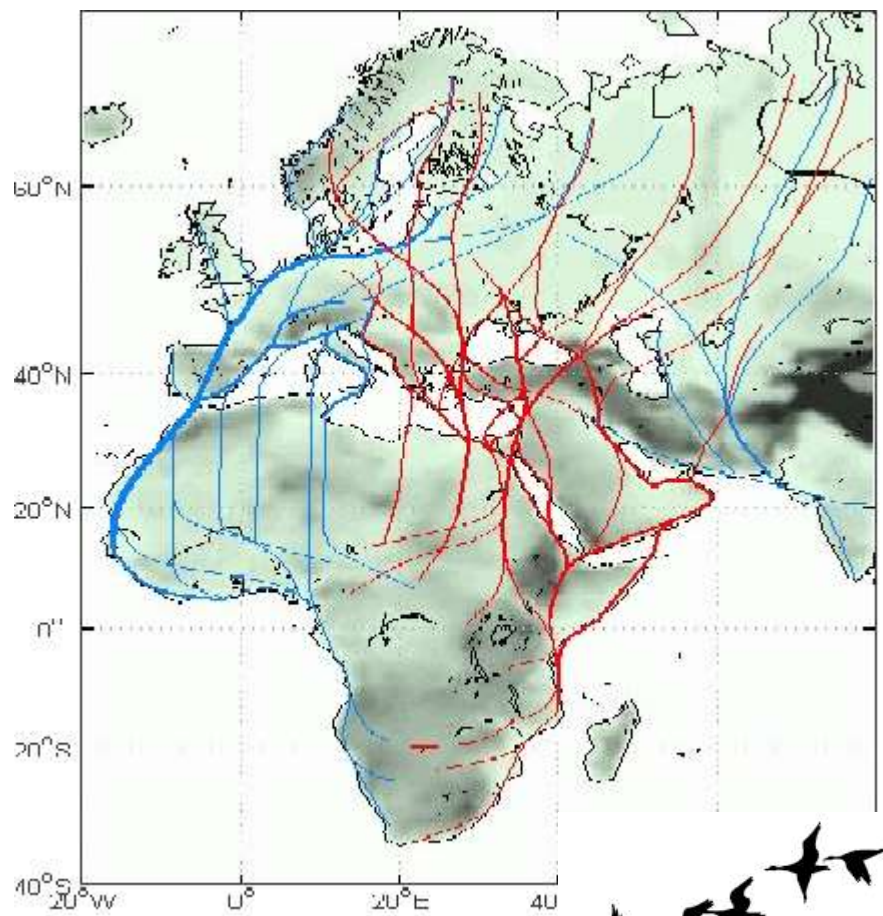
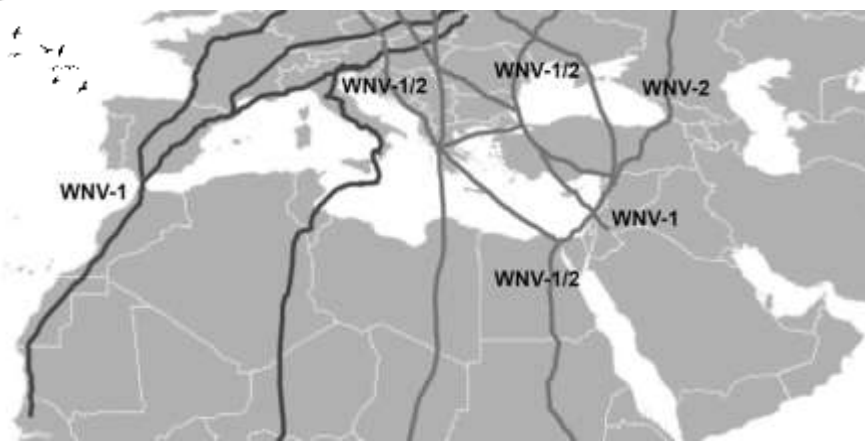
2015



Predicted probability of WNV infection:

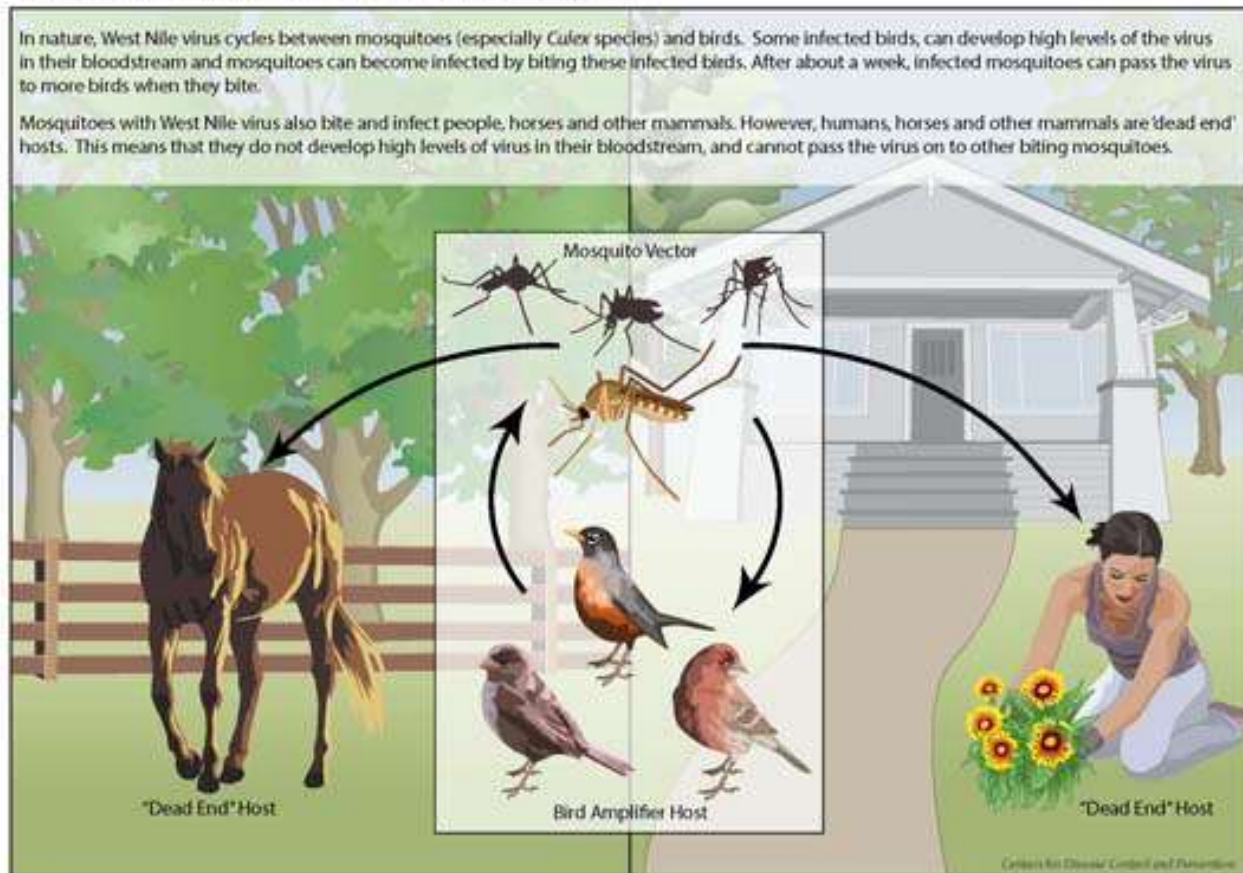


Migrations transcontinentales d'espèces d'oiseaux et VNO



Revenons un instant sur le cycle de transmission !

West Nile Virus Transmission Cycle



https://microbewiki.kenyon.edu/index.php/West_Nile_Virus_in_Birds

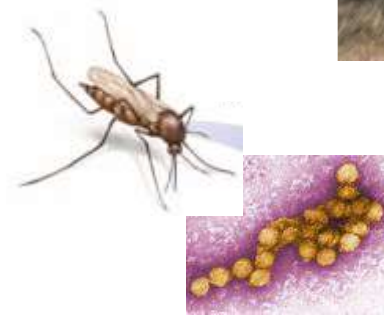
Les communautés locales sont la plupart du temps riches en espèces...



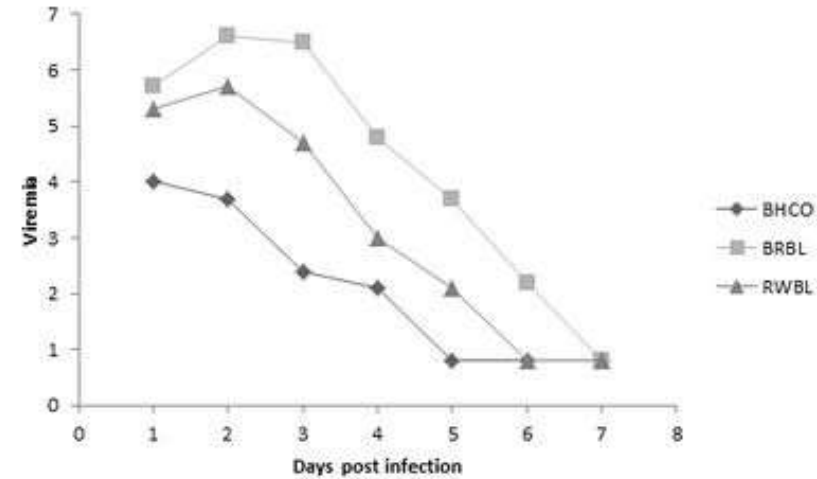
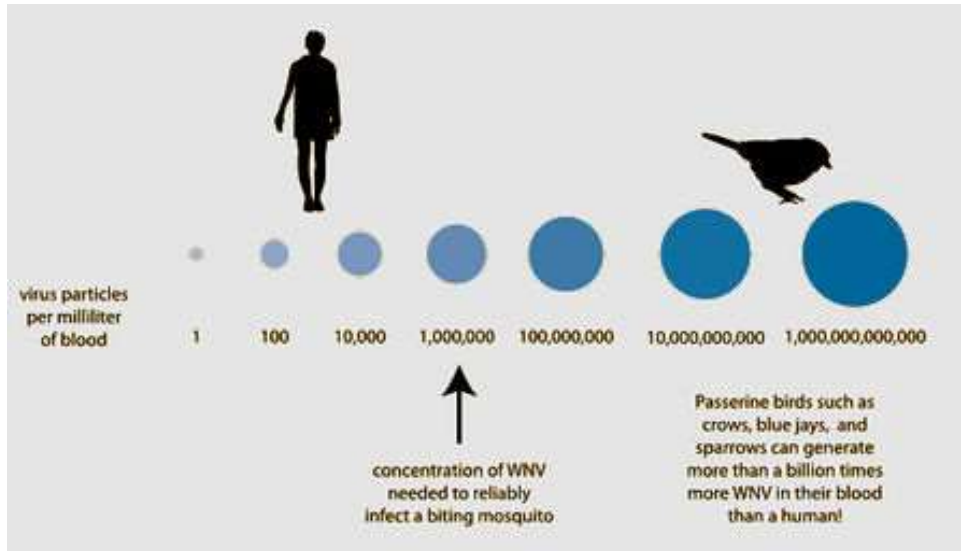
Quelles peuvent être les implications d'un système riche vs pauvre en espèces hôtes dans la transmission infectieuse du VNO ?

Communauté riche en espèces

Communauté pauvre en espèces



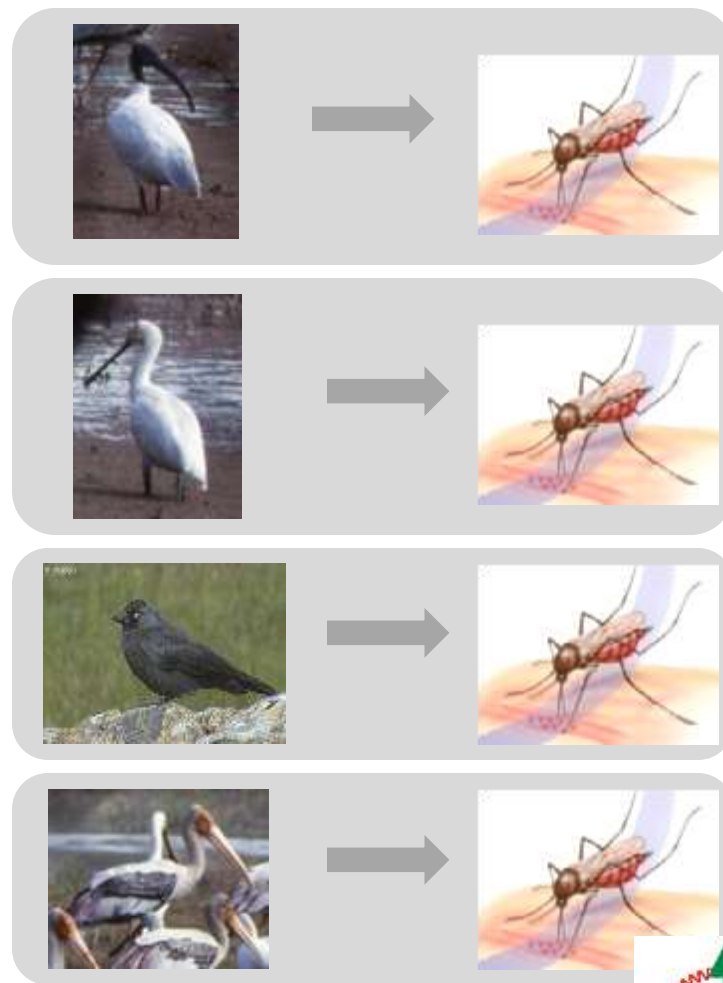
Des niveaux de résistance/susceptibilité différentes entre espèces d'oiseaux, et donc des rôles dans la propagation différents



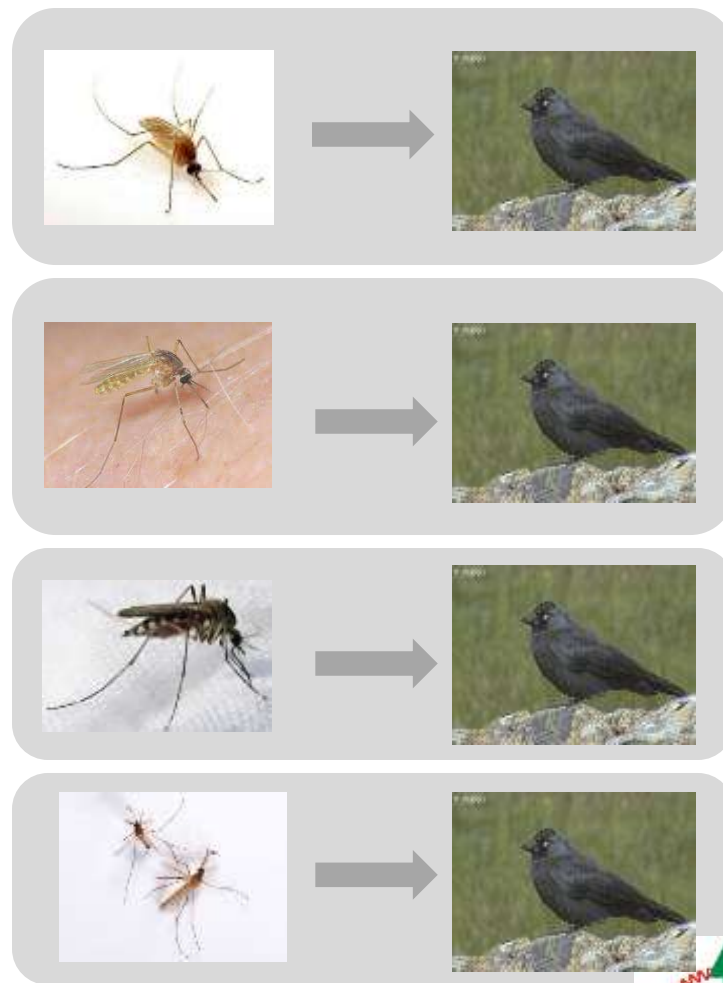
BHCO=Brown-Headed Cowbird (*Molothrus ater*)
 BRBL=Brewer's Blackbird (*Euphagus cyanocephalus*)
 RWBL=Red-winged Blackbird (*Agelaius phoeniceus*)



Communauté plus ou moins riche en espèces de réservoirs

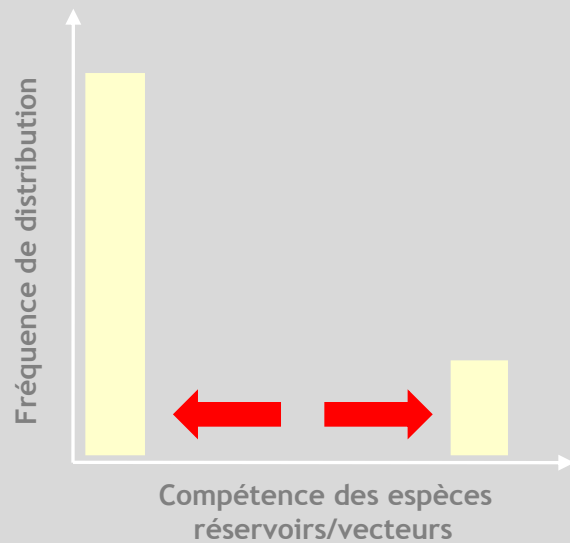


Communauté plus ou moins riche en espèces de vecteurs



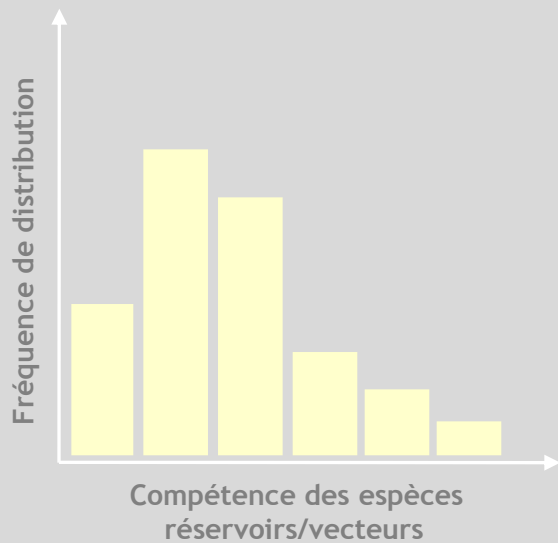
Nécessité de prendre en compte la transmission infectieuse en considérant l'ensemble des constituants

Distribution souvent "acceptée"
de compétences des espèces hôtes

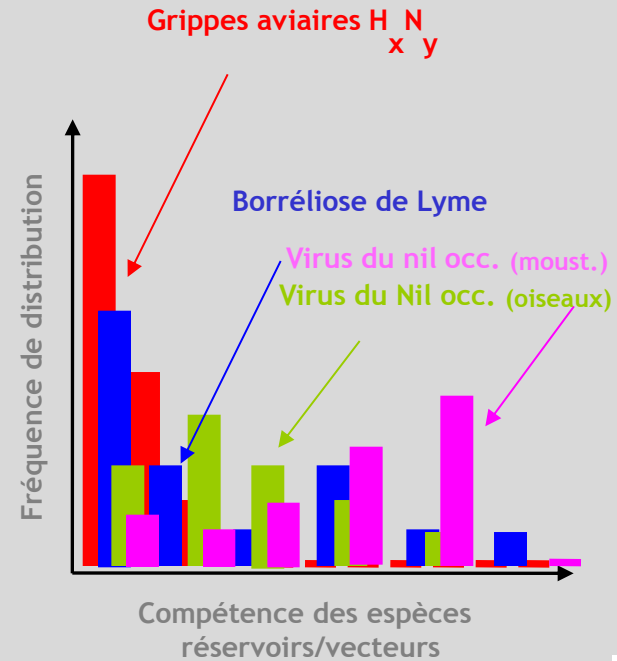


Nécessité de prendre en compte la transmission infectieuse en considérant l'ensemble des constituants

Distribution théorique de compétences des espèces hôtes



Ce que l'on observe réellement

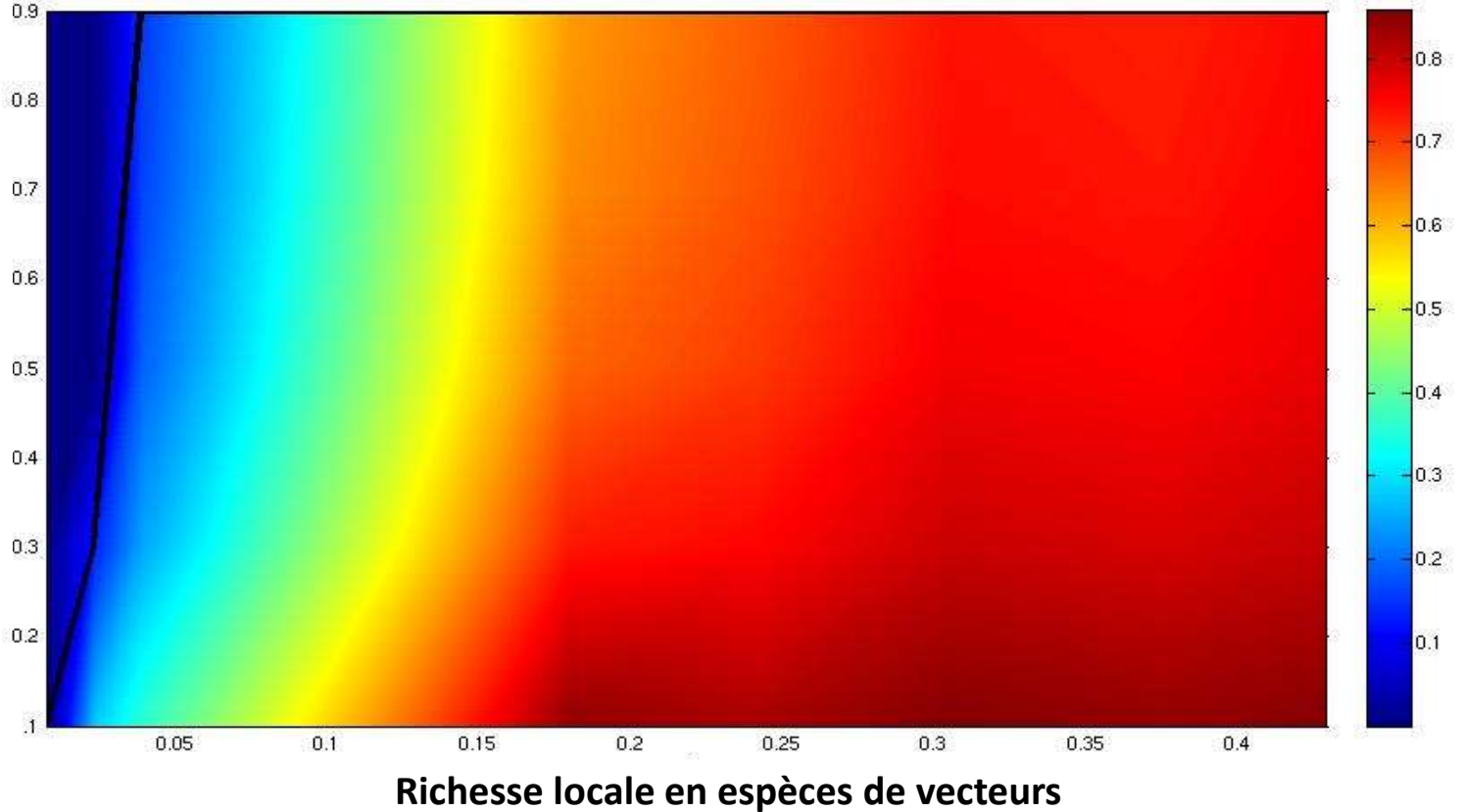


L'exemple de la transmission du virus du Nil occidental

Forte proportion d'espèces pas ou peu compétentes

Compétence globale des espèces réservoirs

Forte proportion d'espèces compétentes à très compétentes

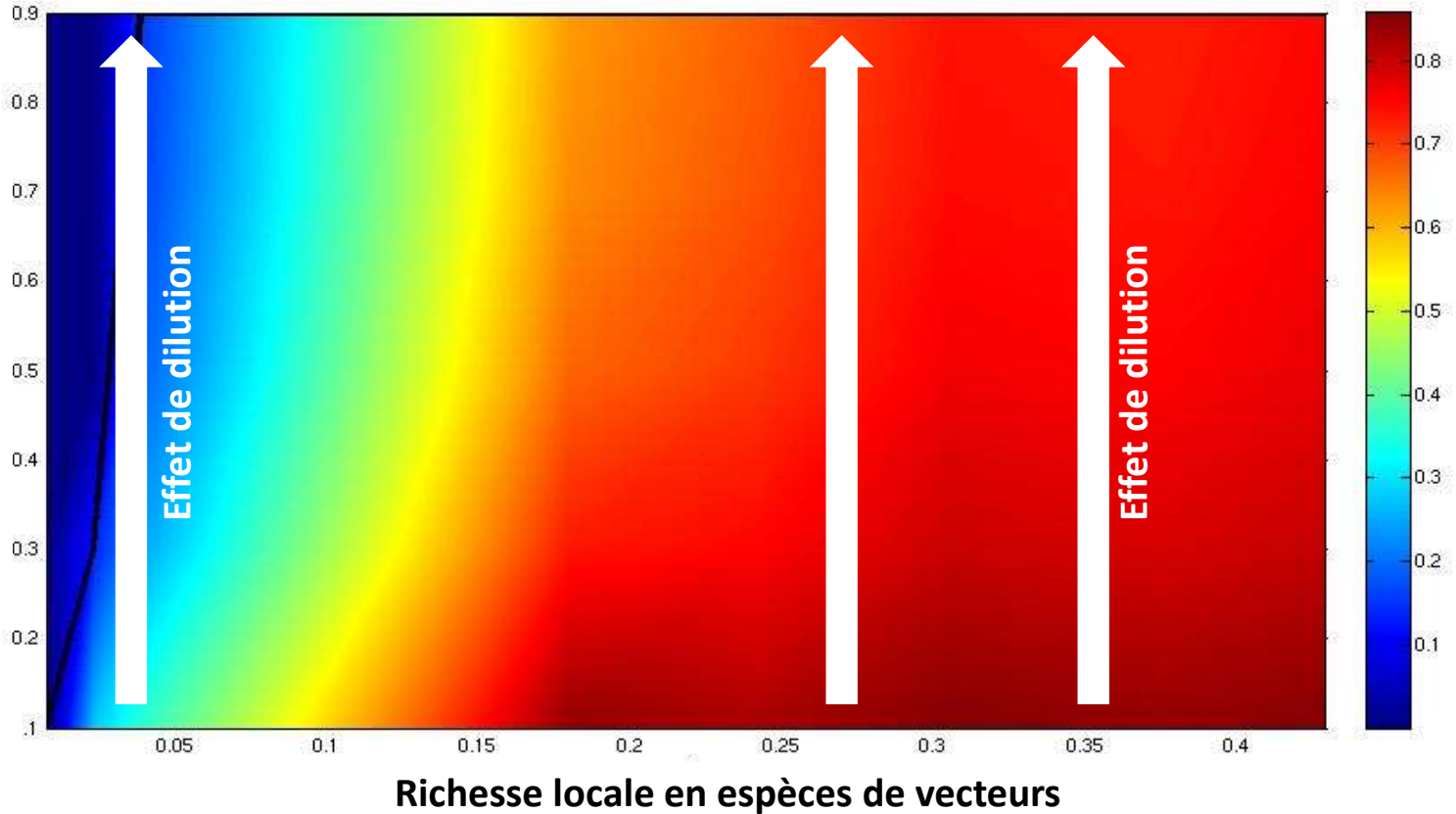


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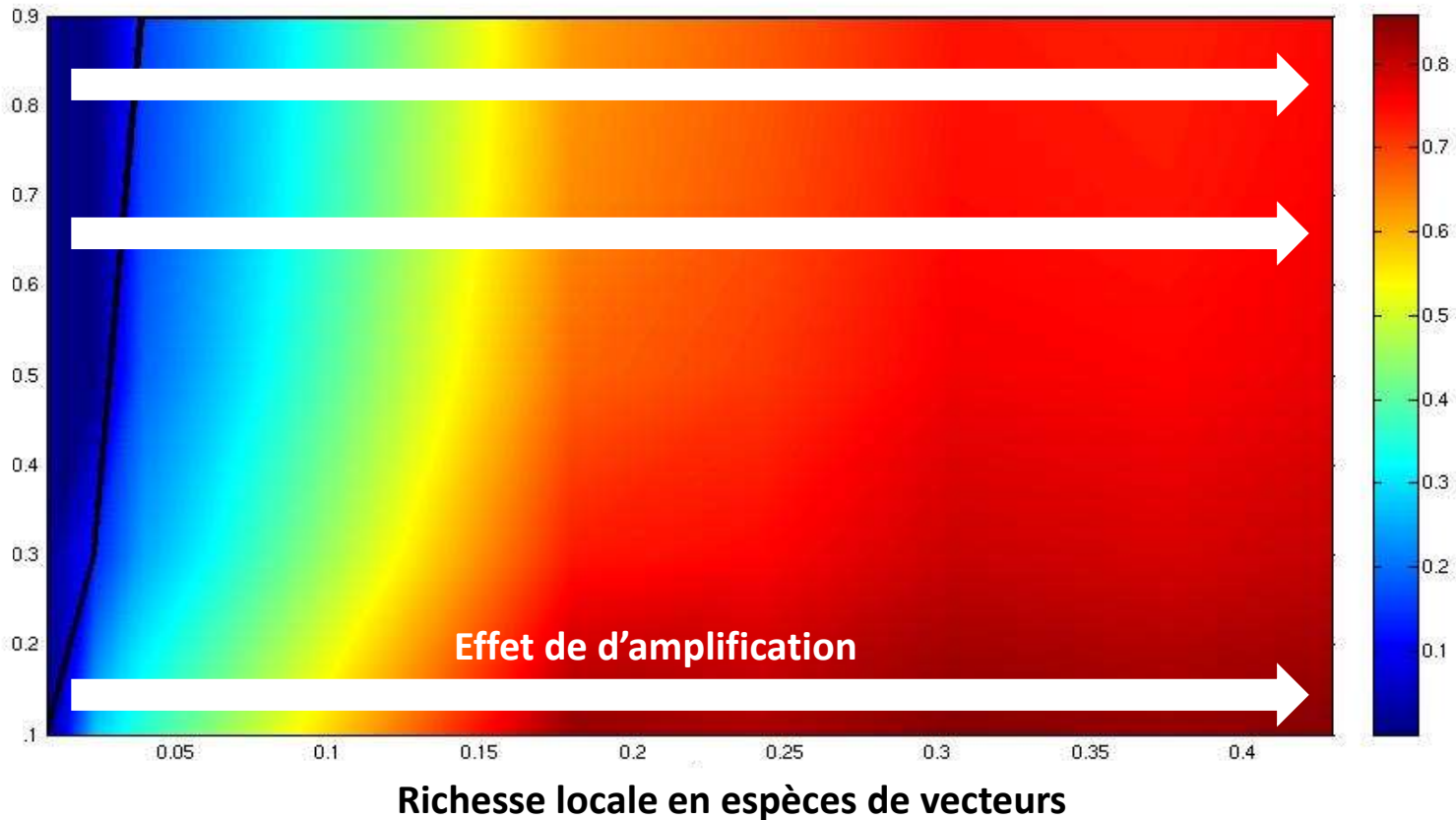


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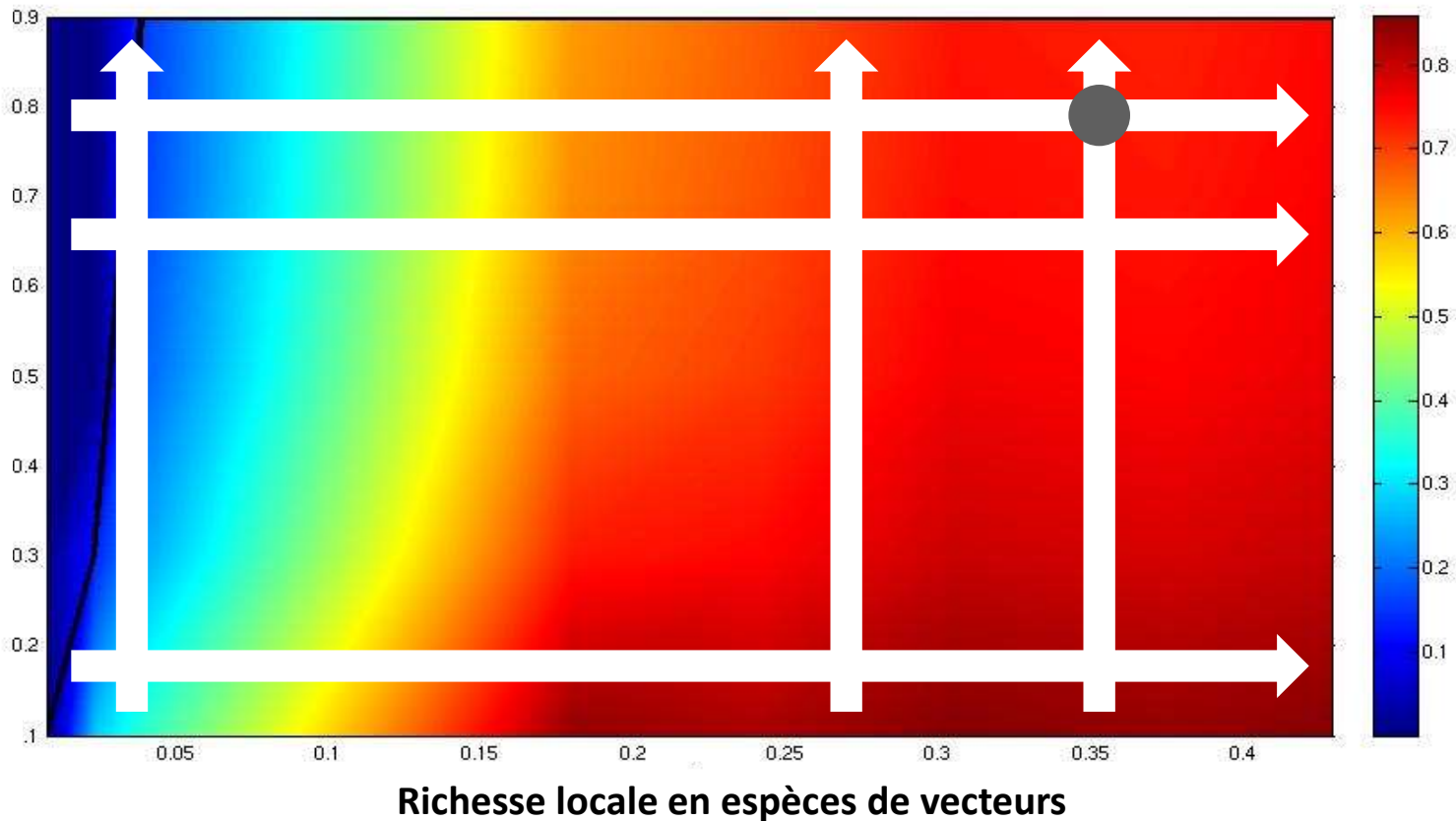


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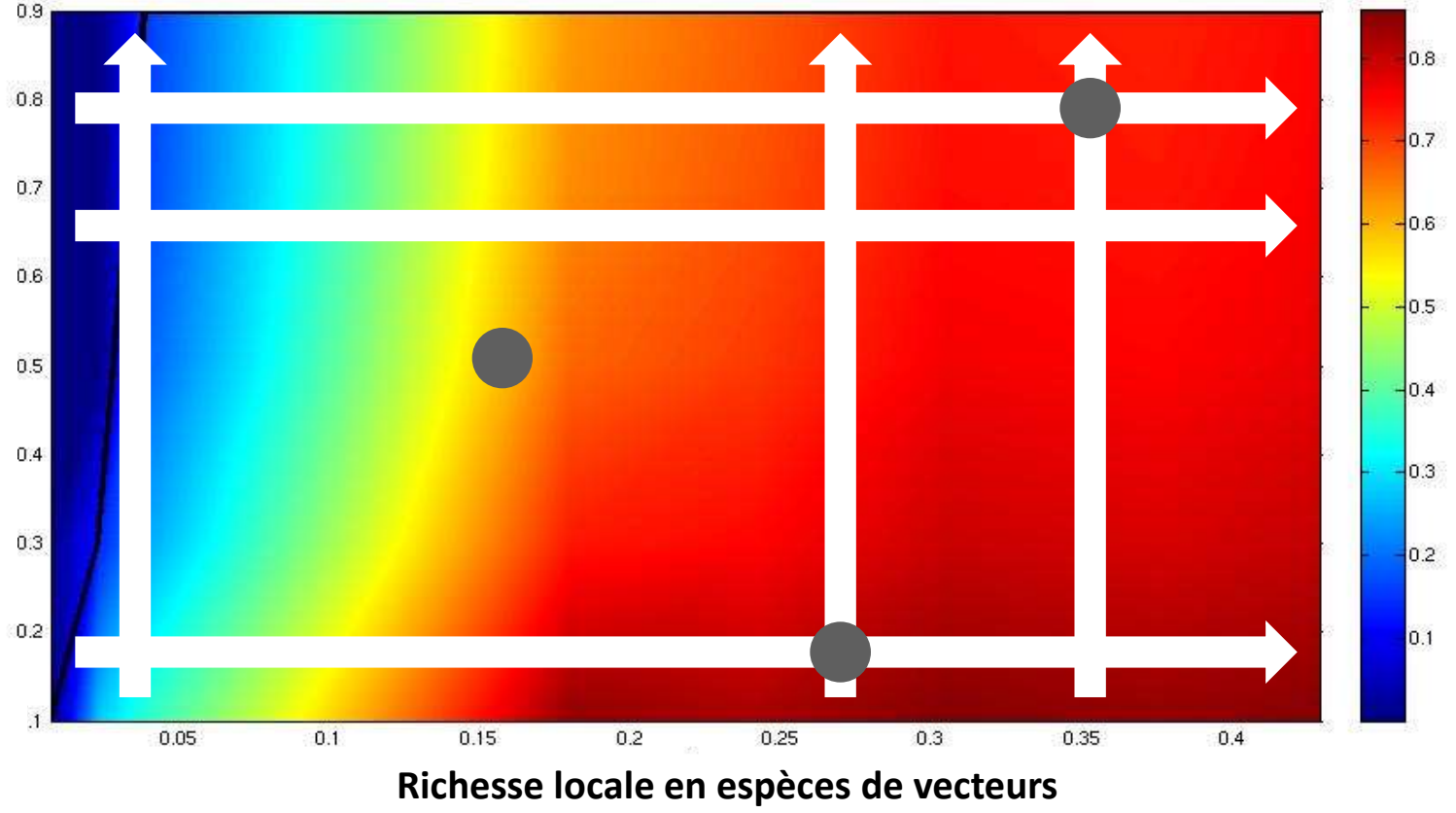


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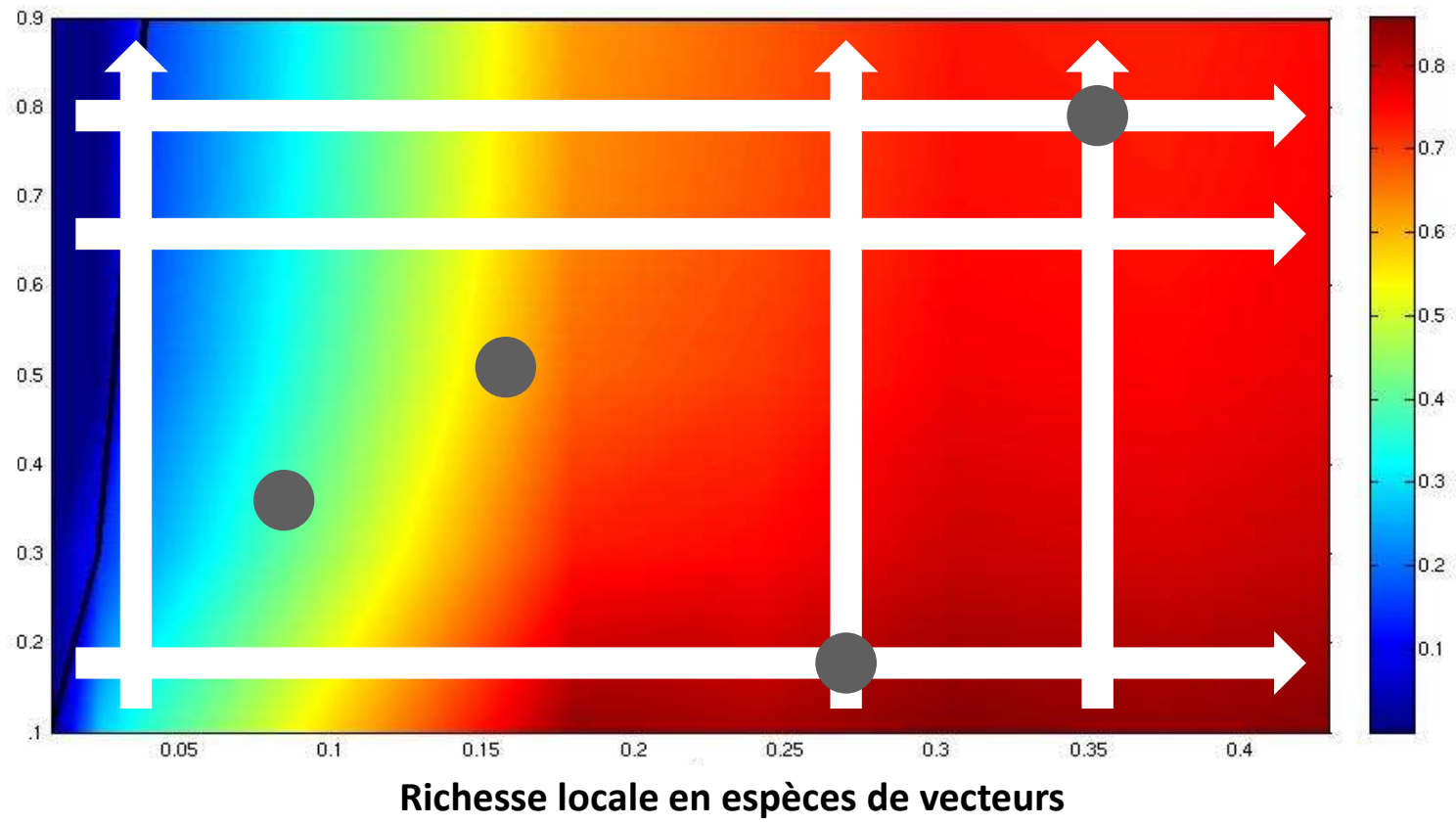


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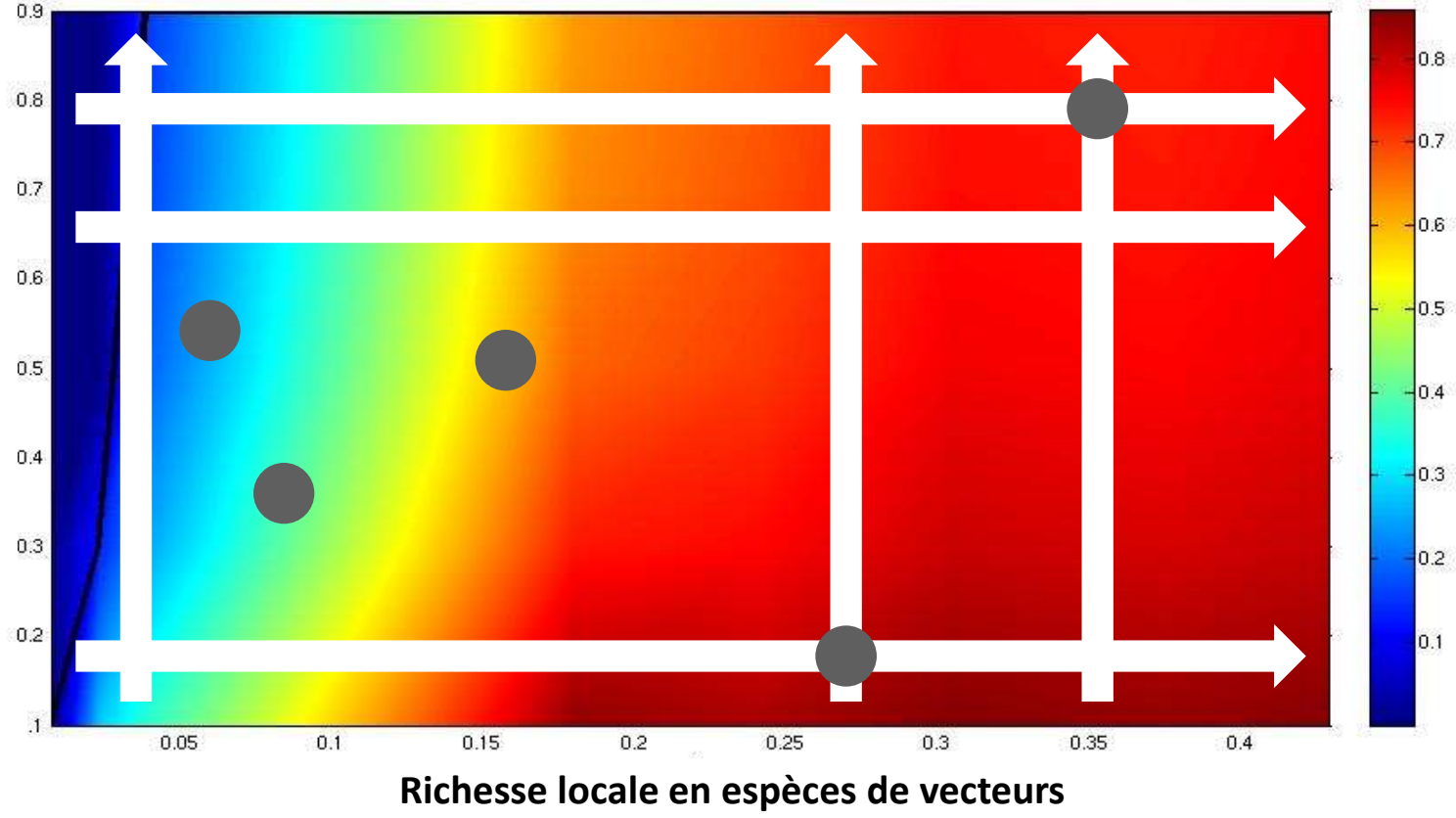


L'exemple de la transmission du virus du Nil occidental

Forte proportion d'espèces pas ou peu compétentes

Compétence globale des espèces réservoirs

Forte proportion d'espèces compétentes à très compétentes



L'exemple de la transmission du virus du Nil occidental

Virus du Nil occ. (Camargue)

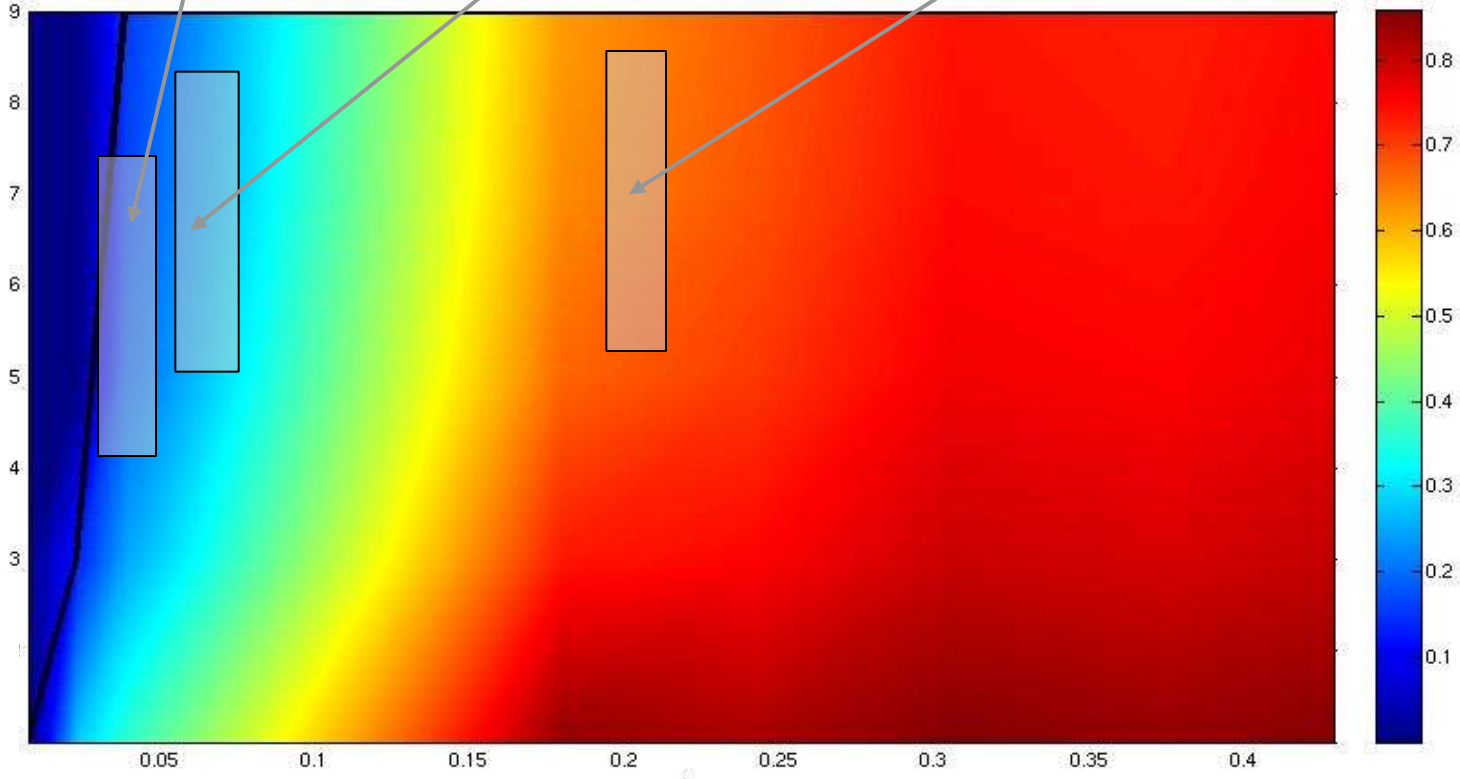
Virus du Nil occ. (Louisiane)

Virus du Nil occ. (Californie)

Forte proportion d'espèces pas ou peu compétentes

Forte proportion d'espèces compétentes à très compétentes

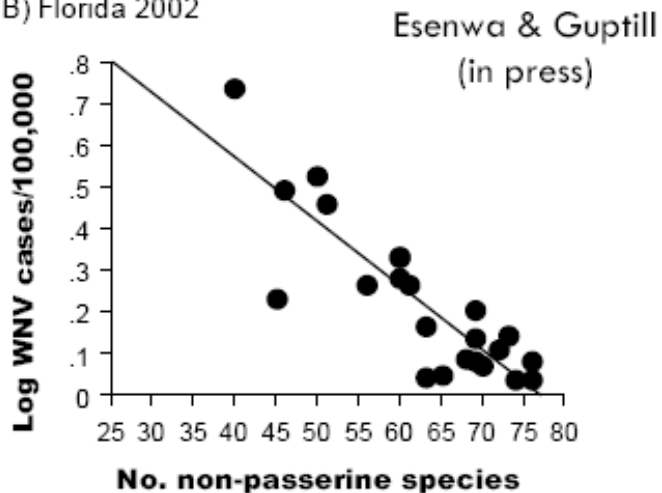
Compétence globale des espèces réservoirs



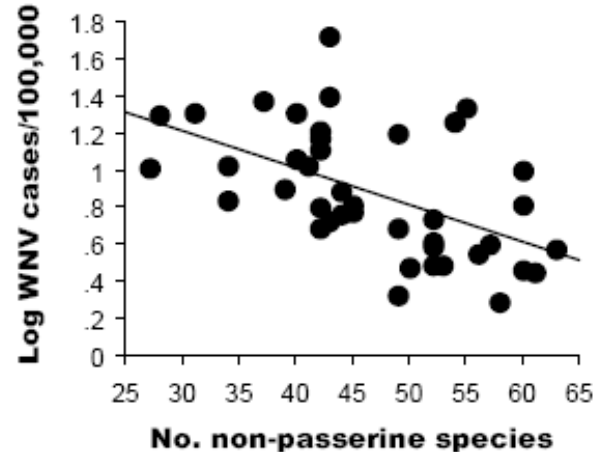
Richesse locale en espèces de vecteurs

Effet de dilution et nombre de cas de malades de la fièvre du VNO aux EUA

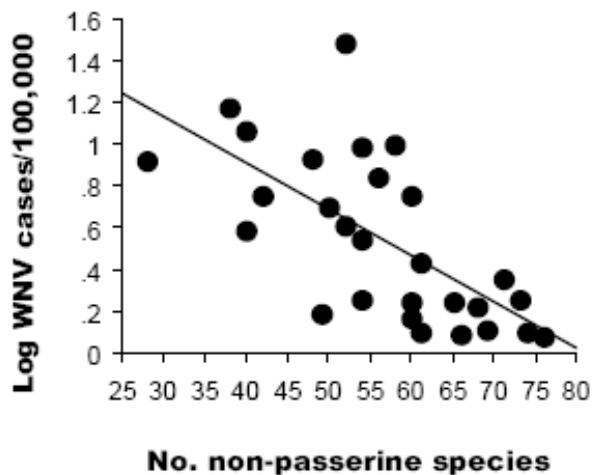
B) Florida 2002



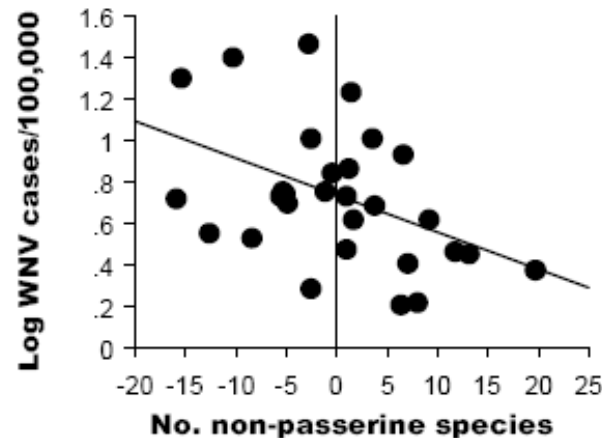
D) Louisiana 2002



C) Florida 2003



E) Louisiana 2003



Importance du changement d'hôtes par les insectes *Culex* dans la transmission du virus

OPEN ACCESS Freely available online

PLoS BIOLOGY

West Nile Virus Epidemics in North America Are Driven by Shifts in Mosquito Feeding Behavior

A. Marm Kilpatrick^{1*}, Laura D. Kramer², Matthew J. Jones², Peter P. Marra^{3,4}, Peter Daszak¹

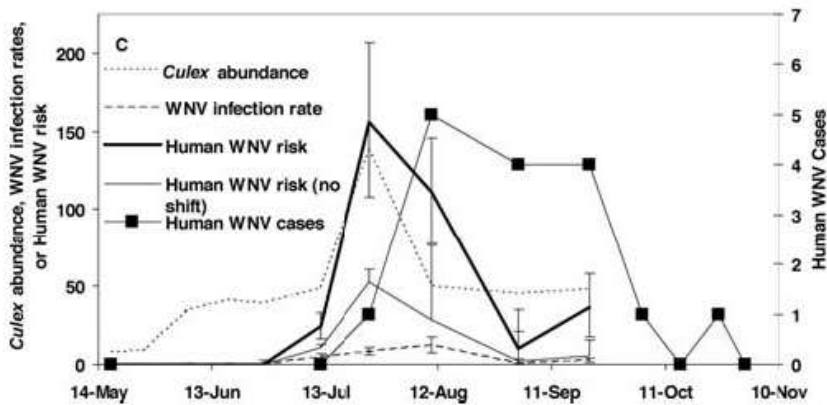


Figure 1. *Cx. pipiens* Feeding Patterns, Avian Population Dynamics, and West Nile Virus Epidemiology

(C) Abundance of *Culex* mosquitoes per trap-night, *Culex* WNV infection rate (1,000 * infection prevalence, ± 1 SE), estimated human WNV infection risk (± 1 SE), calculated as the product of mosquito abundance, WNV infection rate, and the time-varying probability of feeding on humans (Human risk) or the June probability, 0.04 (Human risk – no shift), and the number of human WNV cases in Maryland in 2004.

DOI: 10.1371/journal.pbio.0040082.g001

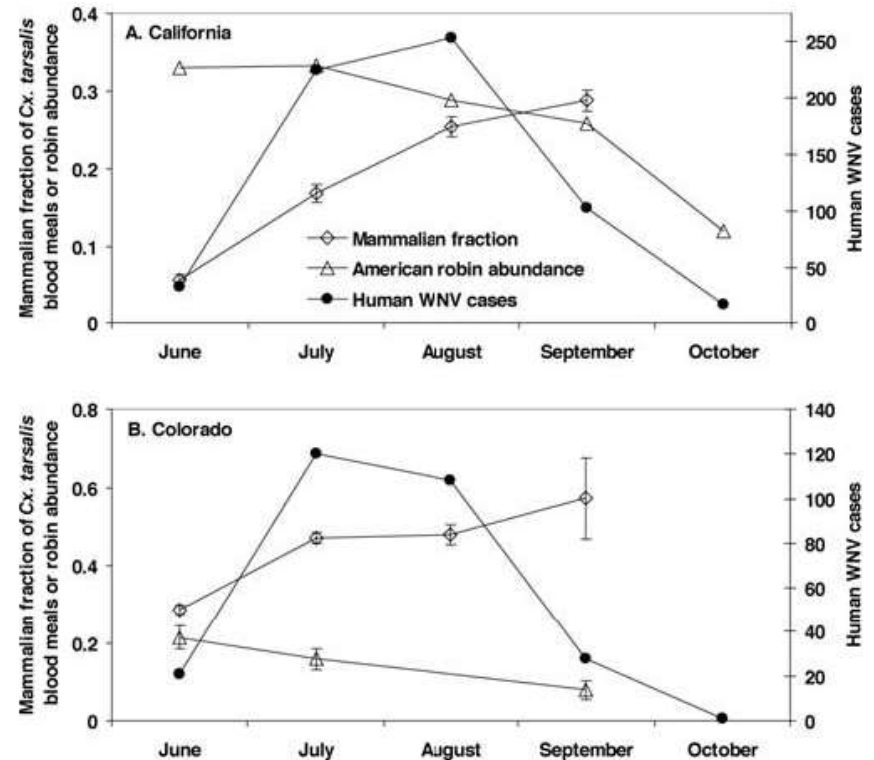


Figure 2. *Cx. tarsalis* Feeding Patterns, Avian Population Dynamics, and West Nile Virus Epidemiology

Fraction of *Cx. tarsalis* feedings from mammals (± 1 SE), abundances of American robins [birds/survey in (A), birds/hectare ± 1 SD in (B)], and the number of human WNV cases in 2004 in California (A) and Colorado (B). DOI: 10.1371/journal.pbio.0040082.g002

Transmission du virus du Nil occidental. Ce qu'il faut retenir !

- ✓ L'une des transmissions **les plus complexes** à intégrer
- ✓ La dynamique de transmission dépend des **communautés d'espèces réservoirs** et **d'espèces de moustiques vecteurs**
- ✓ Ces communautés d'espèces peuvent elles-mêmes être **sensibles aux modifications d'habitats** ; la présence de cas en ville doit être liée à certaines espèces d'oiseaux (et d'insectes) adaptées aux villes
- ✓ **Les différences de profils** « éco-épidémiologiques » **entre l'Europe et les régions néarctiques** d'Amérique du nord sont en grande partie **dues à la composition des faunes**
- ✓ **Les habitudes alimentaires et le changement d'hôtes** de certaines espèces de *Culex* (oiseau vers mammifère dont humain) sont aussi **importants pour comprendre le VNO**
- ✓ Aux EUA, la **possibilité d'hybridation** entre sous-espèces de *Culex* (expérimental) et le **changement d'hôtes** accroîtrait la transmission du virus
- ✓ (En Espagne), **l'aléa viral** est maximal dans les zones à **forte abondance du moustique** *Cx perexiguus* et **non occupées par l'humain**

Remerciements

Les JNI 2018, Nantes et ses organisateurs pour leur invitation, en particulier Pr. F. Raffi

L'Institut de recherche pour le développement (IRD)

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L'Université de Montpellier (UM)

L'École des hautes études en santé publique (EHESP)

L'Institut national de la recherche agronomique (Inra)

La Fondation pour la recherche sur la biodiversité (FRB)

Les LabEx CEBA (Guyane) et CEMEB (Montpellier)

Le programme international U.N. FutureEarth / OneHealth

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https://microbewiki.kenyon.edu/index.php/Nile_Virus_in_Birds

<https://ecdc.europa.eu/en/news-events/epidemiological-update-west-nile-virus-transmission-season-europe-2017>



DIFFERENCE BETWEEN ANOPHELES, CULEX AND AEDES

Anopheles



Most active at dawn and dusk, but also during the night.

Malaria

Culex



Most active at dawn and dusk, but also during the night.

West Nile Virus

Aedes



Aggressive day biter

*Dengue
Yellow Fever
West Nile Virus*

SCIENTIFIC REPORTS

OPEN

Mosquito community influences West Nile virus seroprevalence in wild birds: implications for the risk of spillover into human populations

Josué Martínez-de la Puente^{1,2,3,4*}, Martina Ferraguti¹, Santiago Ruiz^{2,3,4}, David Roiz^{1,2,3}, Francisco Lorente¹, Elisa Pérez-Ramírez¹, Miguel Ángel Jiménez-Clavero^{3,4}, Ramón Sorriquer^{1,2,3} & Jordi Figuerola^{1,2,3,4}

Mosquito community composition plays a central role in the transmission of zoonotic vector-borne pathogens. We evaluated how the mosquito community affects the seroprevalence of West Nile virus (WNV) in house sparrows along an urbanisation gradient in an area with the endemic circulation of this virus. We sampled 2544 birds and 340829 mosquitoes in 45 localities, analysed in 15 groups, each containing one urban, one rural and one natural area. WNV seroprevalence was evaluated using an epitope-blocking ELISA kit and a micro virus-neutralization test (VNT). The presence of WNV antibodies was confirmed in 1.96% and 0.67% of birds by ELISA and VNT, respectively. The VNT-seropositive birds were captured in rural and natural areas, but not in urban areas. Human population density was zero in all the localities where VNT-positive birds were captured, which potentially explains the low incidence of human WNV cases in the area. The prevalence of neutralizing antibodies against WNV was positively correlated with the abundance of the ornithophilic *Culex perexiguus* but negatively associated with the abundance of the mammophilic *Ochlerotatus caspius* and *Anopheles atroparvus*. These results suggest that the enzootic circulation of WNV in Spain occurs in areas with larger populations of *Cx. perexiguus* and low human population densities.

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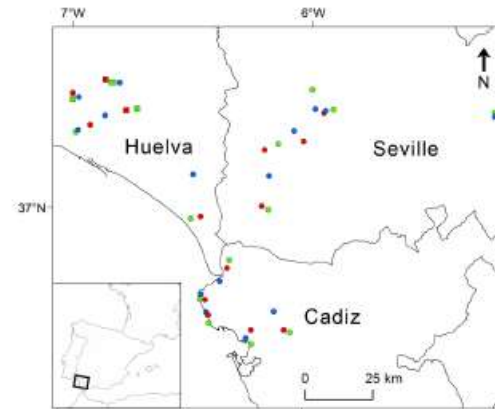


Figure 1. Distribution of the 45 studied localities that consisted of 15 urban (blue), 15 natural (green) and 15 rural (red) areas. Localities with birds with WNV positive sera according to VNT analyses are marked with squares. This map was created using ArcGIS v10.2.1 (ESRI, Redland).

	<i>est</i>	<i>z</i>	<i>p</i>
Mosquito species richness	2.24	2.18	0.03
<i>Cx. perexiguus</i>	1.93	2.04	0.03
<i>Cx. theileri</i>	-2.81	2.41	0.02
<i>Oc. caspius</i>	-2.54	2.14	0.02
Explained variance	35%		

Table 2. Results of the LMMs explaining variance in WNV seroprevalence estimated by ELISA (N = 45 localities). Only estimate (*est*), *z* and *p* values of the independent variables included in the final LMMs are shown; significant associations are marked in bold. Habitat category and the number of *Cx. pipiens* captured did not significantly improve the fit of the models.

	<i>est</i>	<i>z</i>	<i>p</i>
Mosquito species richness	0.77	1.72	0.09
<i>Cx. modestus</i>	-0.69	1.64	0.10
<i>Cx. perexiguus</i>	1.39	2.82	0.01
<i>Cx. theileri</i>	-0.92	1.87	0.06
<i>Oc. caspius</i>	-0.94	2.02	0.04
<i>An. atroparvus</i>	-1.01	1.99	0.05
Explained variance	44%		

Table 3. Results of the LMMs explaining variance in WNV seroprevalence estimated by micro virus-neutralization test (VNT) (N = 45 localities). Only estimate (*est*), *z* and *p* values of the independent variables included in the final LMMs are shown; significant associations are marked in bold. Habitat category and the number of *Cx. pipiens* captured did not significantly improve the fit of the models.

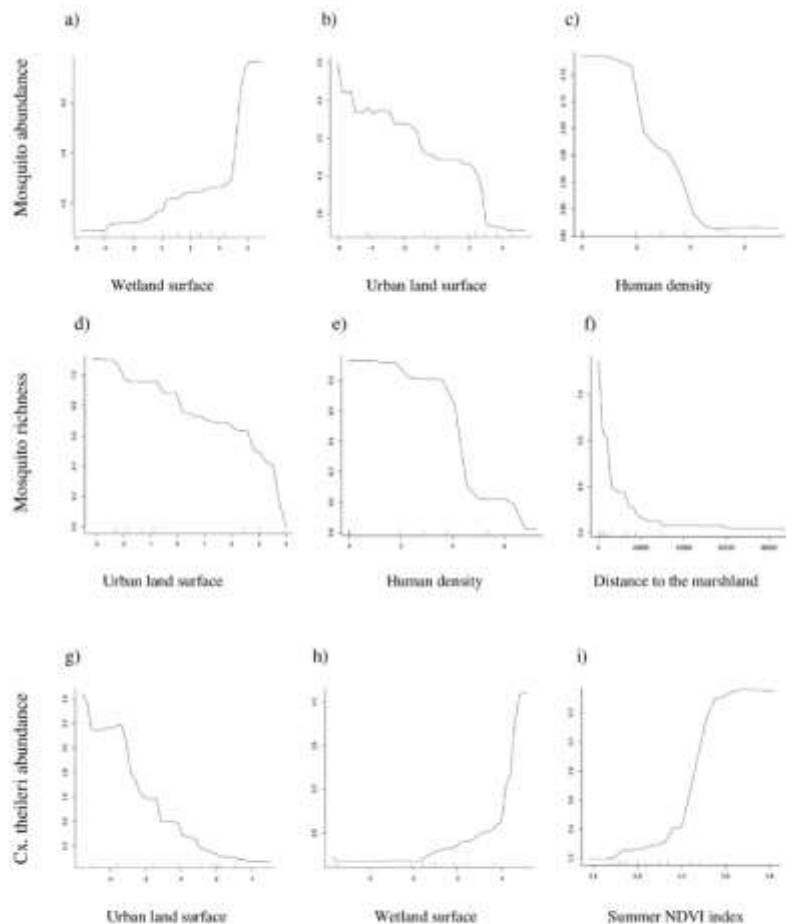


Figure 2. Partial dependence plot for mosquito log-transformed captures and: (a) the percentage of land area covered by wetlands (log ratio transformed); (b) the percentage of land area covered by urban areas (log ratio transformed); (c) human population density (log-transformed). Partial dependence plot for species richness (number of different species) and: (d) the percentage of land area covered by urban areas (log ratio transformed); (e) human population density (log-transformed); (f) the distance to the nearest marshland (m). Partial dependence plot for *Cx. theileri* captures and: (g) the percentage of land area covered by urban areas (log ratio transformed); (h) the percentage of land area covered by wetlands (log ratio transformed); (i) the summer NDVI index. Partial dependence is the dependence of the probability of presence of one predictor variable after averaging out the effects of the other predictor variables in the model.

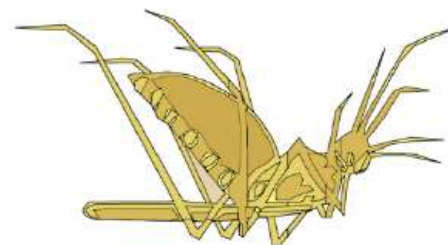
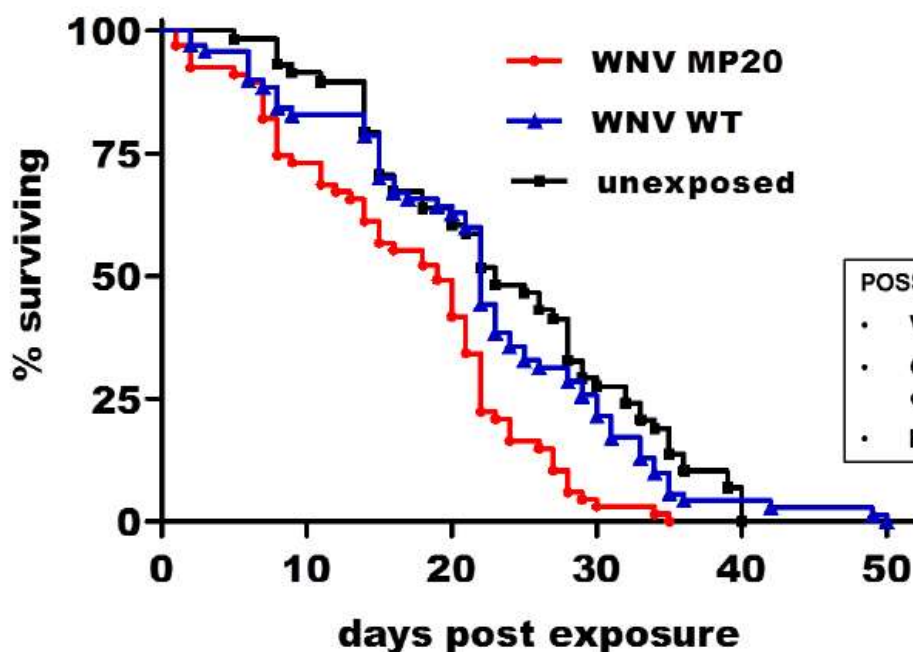
Mosquito variable	Urban	Rural	Natural	χ^2	p
Abundance	2.98 (0.42) ^a	4.27 (0.42) ^b	4.96 (0.41) ^b	19.71	<0.001
Richness	5.46 (0.42) ^a	7.07 (0.42) ^b	7.73 (0.42) ^b	17.88	<0.001
Diversity index	0.34 (0.04) ^a	0.48 (0.04) ^a	0.42 (0.04) ^a	4.84	0.089
<i>An. atroparvus</i>	0.23 (0.35) ^a	0.97 (0.35) ^b	0.91 (0.34) ^b	8.02	0.018
<i>Cx. modestus</i>	0.16 (0.25) ^a	0.39 (0.25) ^{ab}	0.79 (0.24) ^b	10.30	0.006
<i>Cx. perexiguus</i>	0.20 (0.35) ^a	0.78 (0.35) ^{ab}	1.05 (0.34) ^b	7.97	0.019
<i>Cx. pipiens</i>	2.65 (0.25) ^a	2.54 (0.25) ^a	3.33 (0.25) ^b	7.90	0.019
<i>Cx. theileri</i>	0.99 (0.64) ^a	3.20 (0.64) ^b	3.06 (0.62) ^b	24.98	<0.001
<i>Oc. caspius</i>	0.51 (0.38) ^a	1.85 (0.38) ^b	2.29 (0.38) ^b	16.63	<0.001

Table 1. Least square means (SE) of mosquito abundance, species richness, diversity and the abundance of the six commonest species of mosquitoes with respect to habitat categories. χ^2 and p values of each GLMM are shown. Values differing significantly according to Tukey test are marked with different letter.

Mosquito variable	Buffer	% Var. explained	Most important variables in model
Abundance	1	45.35	(+) Wetlands, (-) Urban land, (-) Human density
Richness	250	32.06	(-) Urban land, (-) Human density, (-) Marshland
<i>An. atroparvus</i>	1	41.25	(+) Summer NDVI, (+) Wetlands, (-) Urban land
<i>Cx. modestus</i>	100	19.07	(+) Wetlands, (-) Marshland, (+) Summer NDVI, (-) Winter NDVI
<i>Cx. perexiguus</i>	1	26.59	(+) Summer NDVI, (+) Autumn NDVI, (-) Urban land
<i>Cx. theileri</i>	2	45.55	(-) Urban land, (+) Wetlands, (+) Summer NDVI
<i>Oc. caspius</i>	500	45.76	(-) Marshland, (-) Urban land

Table 2. Results of the random forest analyses on the total mosquito abundance, species richness and the abundance of the five commonest mosquito species in relation to land-use, hydrological and NDVI variables. No significant models were found for mosquito diversity and *Cx. pipiens* abundance. The most important variables from the models are listed in order of importance and the directions of the relationships are shown in brackets. *Land use variables*: Urban land = % of land covered by urban areas (log ratio transformed). *Wetlands* = % of land covered by wetlands (log ratio transformed). *Human density* = people per 250 m² of land area (log-transformed). *Hydrological variables*: Marshland = distance in meters to any type of salt marsh. *NDVI*

Figure 3. Costs of West Nile virus (WNV) infection and resistance and strain-specific effects on survival in *Culex pipiens*. Exposure to mosquito-adapted WNV (MP20) decreases survival with or without establishment of infection (costs of infection and resistance) while exposure to wildtype (WT) WNV does not alter survival. Decreased survival in infected mosquitoes decreases vectorial capacity despite increased vector competence of WNV MP20. Adapted from [89].



POSSIBLE CAUSES OF DECREASED SURVIVAL:

- VIRAL PATHOLOGY- cost of infection
- COST OF IMMUNITY (RNAi and other pathways)- cost of infection and resistance
- INTERACTIONS WITH MICROBIAL COMMUNITY