

# Understanding the ecological drivers of avian influenza virus infection in wildfowl: a continental-scale study across Africa

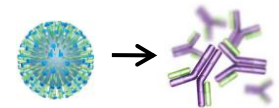
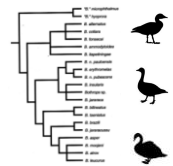
N. Gaidet, A. Caron, J. Cappelle, G. S. Cumming, G. Balança, S. Hammoumi, G. Cattoli, C. Abolnik, R. Servan de Almeida, P. Gil, S. R. Fereidouni, V. Grosbois, A. Tran, J. Mundava, B. Fofana, A. B. Ould El Mamy, M. Ndlovu, J. Y. Mondain-Monval, P. Triplet, W. Hagemeijer, W. B. Karesh, S. H. Newman and T. Dodman

***Proc. R. Soc. B 2011: online***

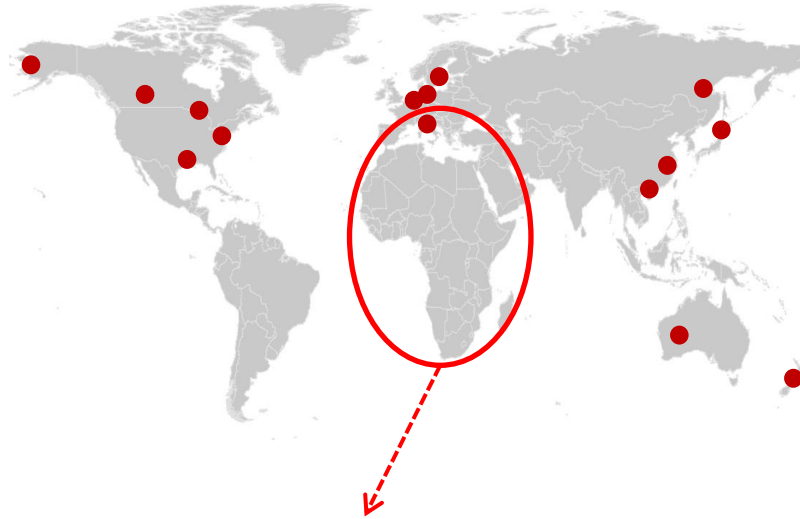


## Potential ecological drivers of AIV prevalence in wildfowl

Environmental transmission	<b>Climate</b> <b>Foraging behaviour</b>	environmental persistence exposure to environmental infection
Inter-individual transmission	<b>Host density</b> <b>Seasonal aggregation</b>	contact rate
Host receptivity	<b>Taxonomy</b>	intrinsic receptivity to infection
Host susceptibility	<b>Geographical origin</b> <b>Age</b>	previous AIV exposure - susceptibility to re-infection
Population immunity	<b>Demographic rates</b> <b>Seasonal peaks in prevalence</b>	turnover of susceptible hosts
Host dispersal	<b>Timing and origin of migrants</b>	source of virus introduction



● *Main long-term AIV surveillance sites*

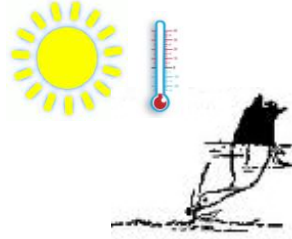


Specific host ecology, climate and seasonality in Afro-tropical regions  
→ specific AIV transmission dynamics and ecological drivers



## Difference between tropical /temperate regions

Climate



Foraging behaviour

Host density

Seasonal aggregation

Taxonomy

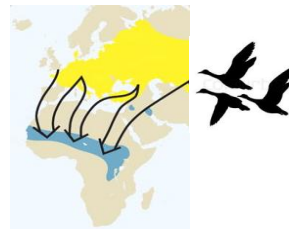
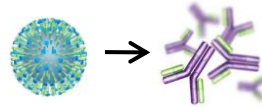
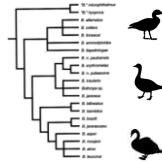
Geographical origin

Age

Demographic rates

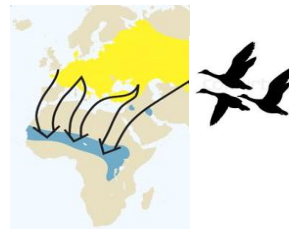
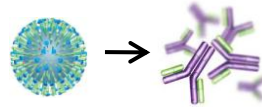
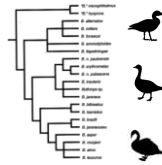
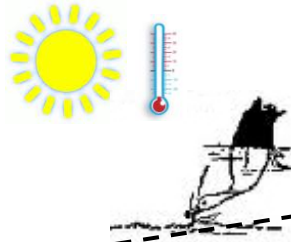
Seasonal peaks in prevalence

Timing and origin of migrants



## Difference between tropical /temperate regions

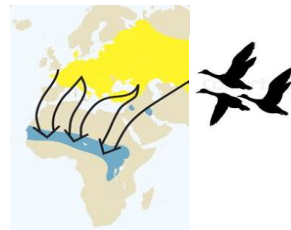
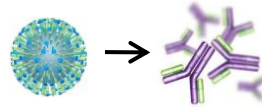
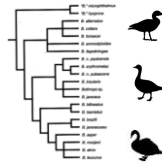
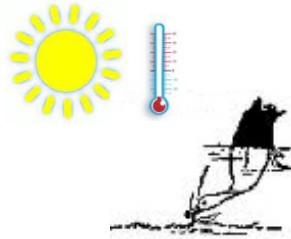
<b>Climate</b> Foraging behaviour
<b>Host density</b> Seasonal aggregation
<b>Taxonomy</b>
<b>Geographical origin</b> <b>Age</b>
<b>Demographic rates</b> Seasonal peaks in prevalence
<b>Timing and origin of migrants</b>



✓ Higher temperatures with lower seasonal variations  
→ shorter environment survival  
→ host density > climatic factors ?

## Difference between tropical /temperate regions

Climate
Foraging behaviour
Host density
<b>Seasonal aggregation</b>
Taxonomy
Geographical origin
Age
Demographic rates
Seasonal peaks in prevalence
Timing and origin of migrants



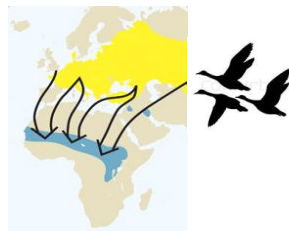
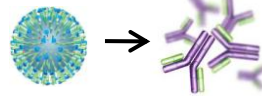
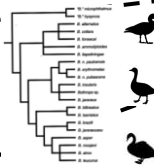
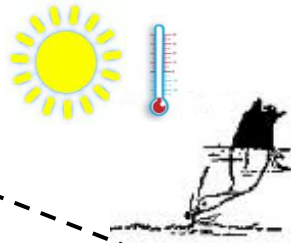
✓ Extreme seasonal variations in the surface of wetlands

→ congregation of wildfowl at permanent wetlands at the end of the dry season

→ influence on AIV seasonal pattern?

## Difference between tropical /temperate regions

Climate
<b>Foraging behaviour</b>
Host density
Seasonal aggregation
<b>Taxonomy</b>
<b>Geographical origin</b>
Age
Demographic rates
Seasonal peaks in prevalence
Timing and origin of migrants



- ✓ Species traits:
- exposure to environmental infection
- intrinsic receptivity to infection
- previous AIV exposure

# Variation in AIV prevalence between cohabiting wildfowl species?



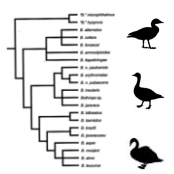
## ✓ Foraging behaviour:



Dabbling



Diving or Grazing



## ✓ Taxonomy:

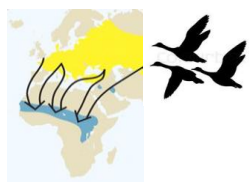
*Anas* species



non *Anas* species

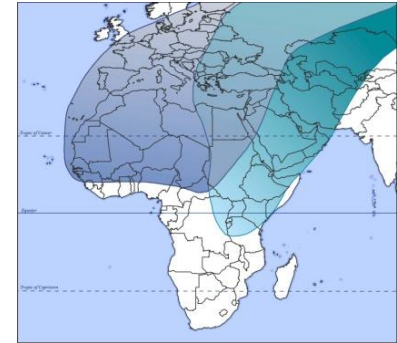






✓ **Migratory behaviour:**

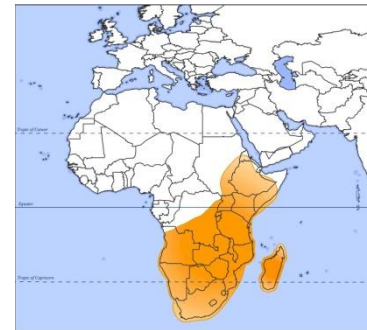
- Eurasian migrants
  - ✓ **Sept. to March**
  - ✓ **Only North of equator**
  - ✓ Mostly **dabbling** duck of the **Anas** genus



- Afro-tropical residents
  - ✓ **Year-round** in sub-Saharan Africa
  - ✓ Dabbling ducks = **Anas** + **non Anas** species
  - ✓ **Anas**: rare in West Africa

*Anas*

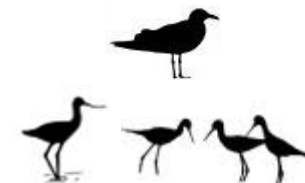
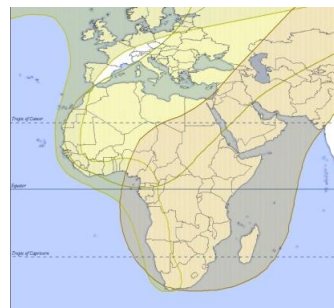
non *Anas*



Regional variations in the composition of the wildfowl community in Africa

→ Test the respective influence of migratory, foraging behaviour and taxonomy

- Other migratory waterbirds



## A continental-scale dataset

### The study:

2006 to 2009

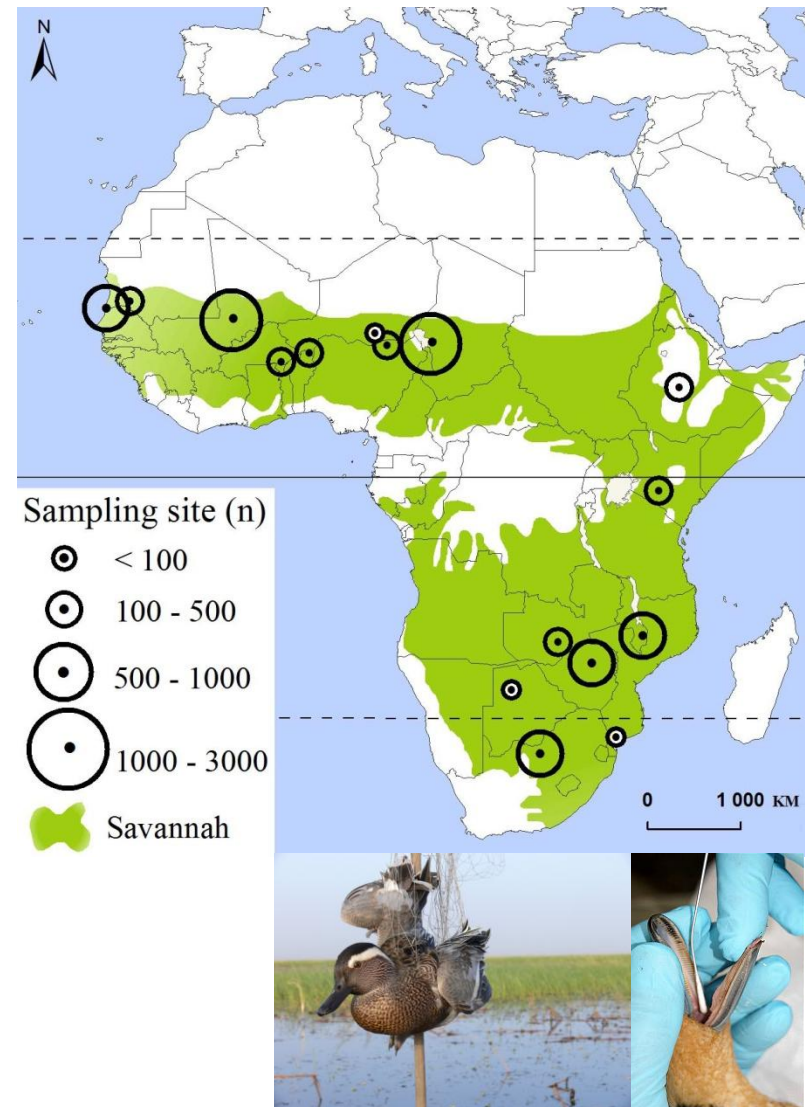
16 sampling sites

55 sampling occasions

> 8,400 birds

Cloacal and/or Oropharyngeal swabs

Real-time RT-PCR (M gene)



## List of explanatory variables tested

**Density** of wildfowl (no. bird/km<sup>2</sup>)

**Composition** of the wildfowl community :

- % Eurasian spp
- % Dabbling spp
- % *Anas* spp

**Climate**: temperatures, potential of evapo-transpiration (PET), aridity index

**Season**: timing relative to

- arrival of Eurasian migrants (1 Sept.)
- end of the dry season

**Species traits**:

- Migratory behaviour
- Foraging behaviour
- Taxonomy

**Routes of virus excretion**: cloacal versus oropharyngeal samples

## Data sources

Variables estimated for each sampling occasion: same year, season and site

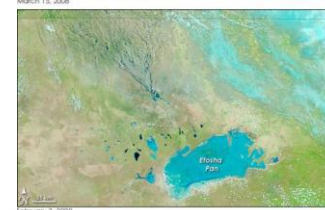
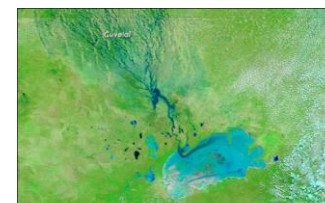
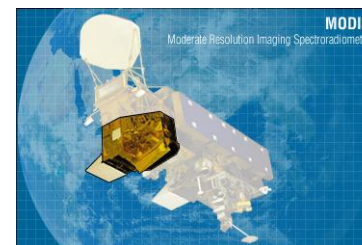
### ✓ **Bird census:**

- aerial counts
- ground counts



### ✓ **Water bodies:** remote sensing

- NDVI + MNDWI - Terra-MODIS images)



### ✓ **End of the dry season:**

- Time series of local rains (TRMM dataset)

### ✓ **Temperatures and aridity:**

- FAO agro-climatic database (NewLocClim)



## Species, seasonal and geographical variations in AIV prevalence

### ✓ **Generalized linear mixed model**

- AIV prevalence  $\sim$  Var 1 + Var 2 + ...
- Year, site and sampling occasion as random effect
- Model comparison based on AICc weights ( $w_i$ )

### ✓ **Analysis procedure:**

- Test alternative explanatory variables successively by permutation  $\rightarrow$  a set of models
- Select alternative variables on the basis of their relative sum of AICc weights ( $\Sigma\omega_i$ )
- Estimate the relative importance of each retained variable by comparing  $\Sigma\omega_i$  among models which included or excluded this variable

## Results

➤ 4 relatively important variables explained the variation in AIV prevalence:

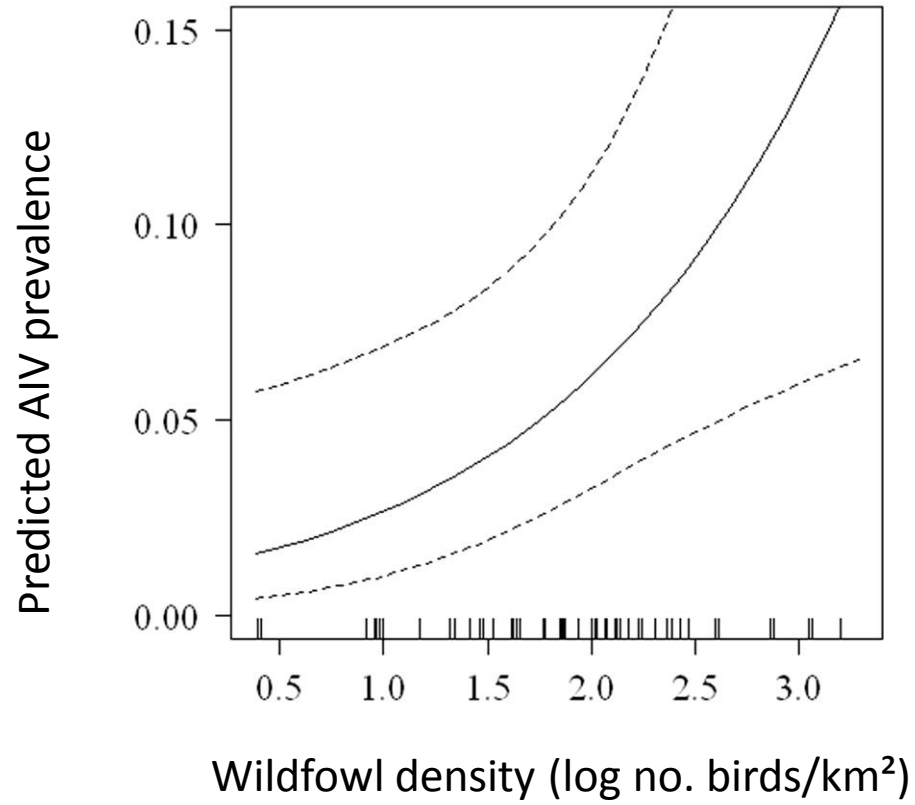
- ✓ **Density** of wildfowl ( $\Sigma \omega_i = 0.88$ )
- ✓ **Season** ( $\Sigma \omega_i = 0.87$ ) : **Timing /arrival Eurasian migrants** > timing / end of the dry season
- ✓ **Species traits** ( $\Sigma \omega_i = 1.00$ ) : **Taxonomy** > Migratory and Foraging behaviour
- ✓ **Source of sample** ( $\Sigma \omega_i = 0.83$ )

➤ Other variables received much less support from the data

- ✓ **Composition** of the wildfowl community ( $\Sigma \omega_i < 0.33$ )
- ✓ **Climate** ( $\Sigma \omega_i < 0.35$ )

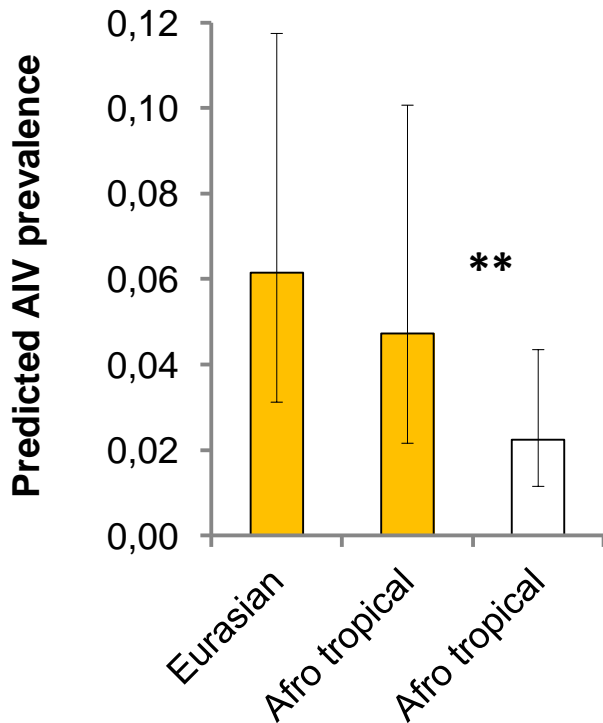
## Results

### Density



## Results

### Species traits - Taxonomy



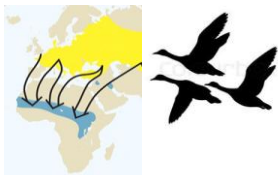
■ *Anas* species  
□ non-*Anas* species

\*\*  $p \leq 0.01$

Prevalence in *Anas* > non-*Anas* species

Difference in intrinsic receptivity to AIV infection?

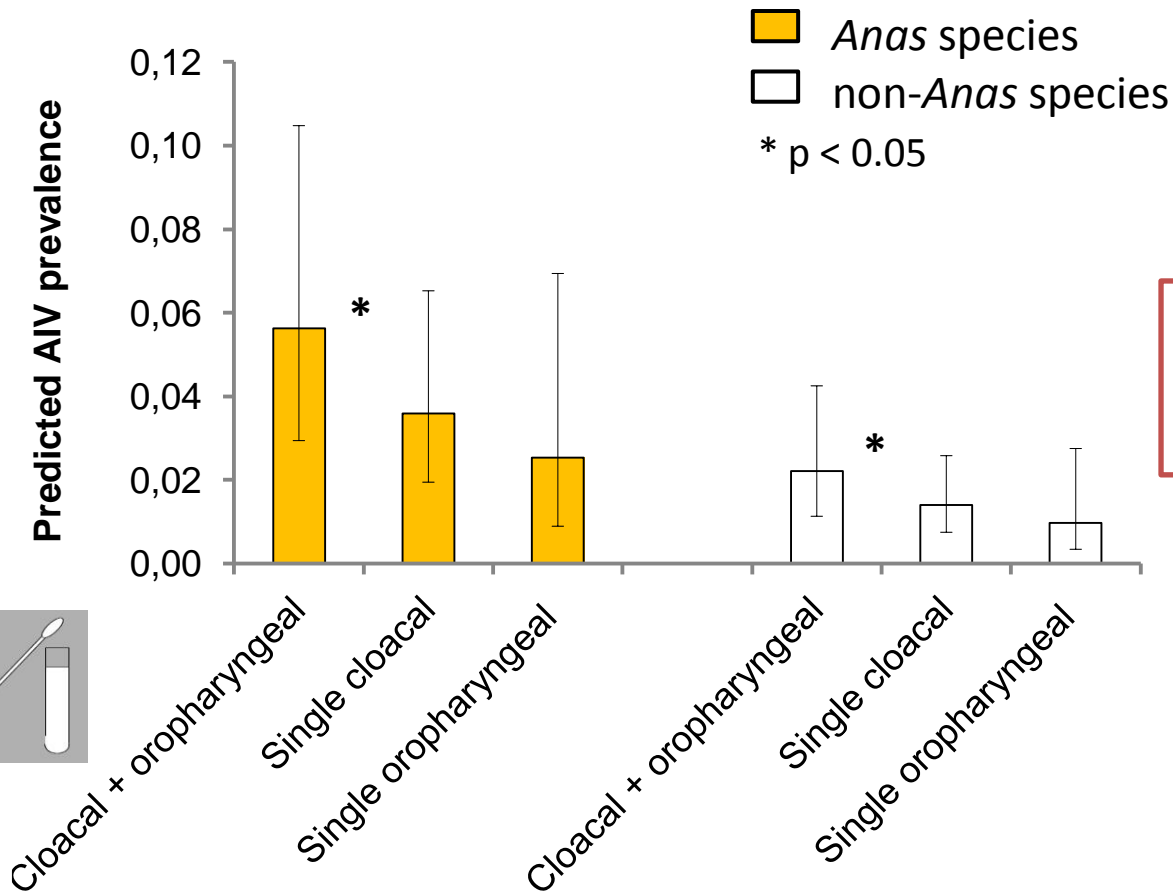
Migratory behaviour



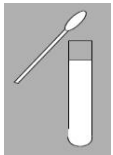


## Results

### Source of sample - Cloacal / Oropharyngeal



Cloacal + Oroph. > Cloacal only  
Cloacal only ~ Oroph. only



→ Importance of both respiratory and digestive tracts for AIV replication

## Conclusions

AIV prevalence related to ecological factors at both species and community levels

- ✓ No difference between Eurasian and Afro-tropical wildfowl:
  - species level (geographic origin)
  - community level (proportion of Eurasian spp/community)
- ✓ Importance of geographical and seasonal variations in wildfowl density:
  - dry season congregation + influx of Eurasian migrants
- ✓ Poor relation with local climate: high temperature constrains year-round in all sites ?

**Inter-individual transmission**  
(short-term)

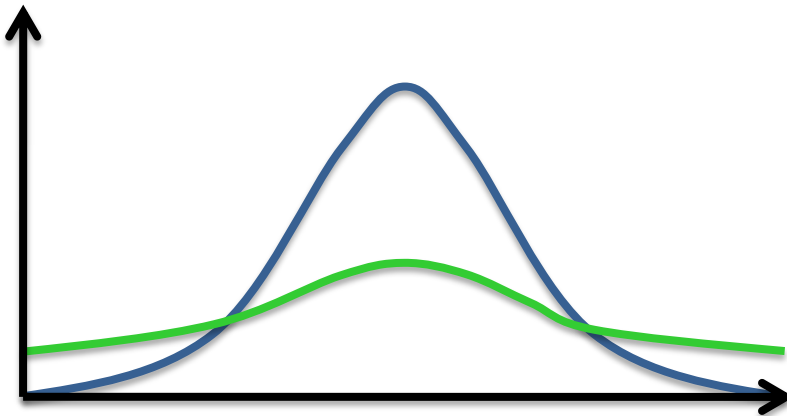


**Indirect transmission**  
(long-term environmental persistence)

## Conclusions

✓ Seasonal variations in AIV prevalence not related to the timing of congregation

	Temperate regions	Tropical regions
breeding period → introduction of immunologically naive juveniles birds	short - synchronised seasonal pulse	extended - asynchronised gradual recruitment
seasonal congregation	short autumn migration flocking	progressive through drying of wetlands



A **lower** and **less variable**  
but **continuous** annual circulation

# Acknowledgments

- **GRIPAVI** project - French Ministry of Foreign Affairs
- **TCP** - FAO
- **GAINS** - USAID
- **New Flubird project** - EU



## PROCEEDINGS OF THE ROYAL SOCIETY B | BIOLOGICAL SCIENCES

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