Potential for spread of HPAI H5N1 by wildfowl: dispersal range and rate determined from a large-scale satellite telemetry

Gaidet N., Cappelle J., Takekawa J.Y. , Prosser D.J. , Iverson S.A. ,

Douglas D.C. , Perry W.M. , Mundkur T. , Newman S.H.

Context

✓ Rapid spread of HPAI H5N1 over Asia, Europe and Africa in 2005-2006

✓ Concurrent reports of mortality events in some migratory wildfowl

✓ Wildfowl are the primary reservoir of AI viruses

→ suspected role in long-distance spread of HPAI H5N1 virus

→ potential range and rate of long-distance dispersal of these viruses by wildfowl?
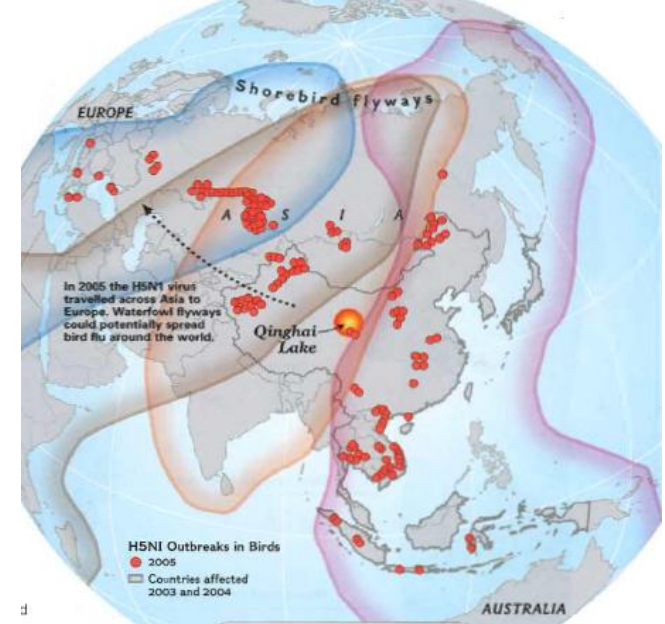
Potential for spread of HPAI H5N1 virus by wildfowl

Consistent findings from several experimental infection studies of wildfowl*:

→ asymptomatic HPAI H5N1 virus shedding in wildfowl for several days

→ potential for virus dispersion as they move?

Capacity for rapid long-distance movements within the time frame of virus shedding?

Probability for timing of infection to coincide with timing of long-distance movements?

*Brown et al. 2006; Brown et al. 2007; Brown et al. 2008; Kalthoff et al. 2008; Keawcharoen et al. 2008; Kwon et al. 2010
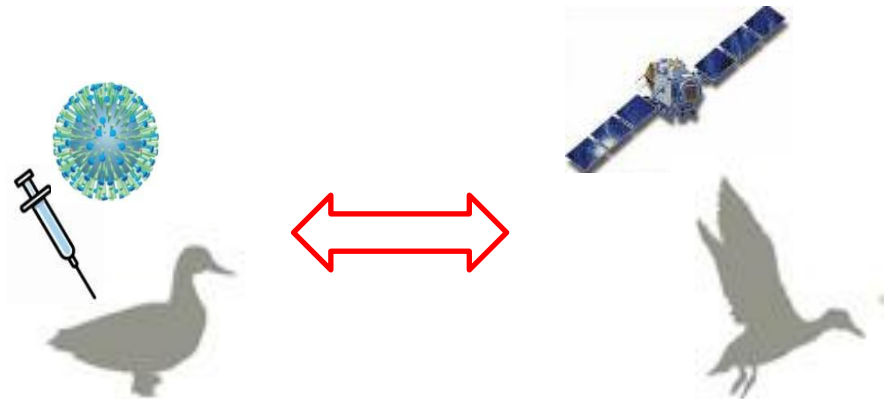
Evaluation of the dispersive potential of HPAI H5N1 by wildfowl

Difficulty of a direct investigation:

- ✓ tracking a known viremic free-living bird in the process of migration?

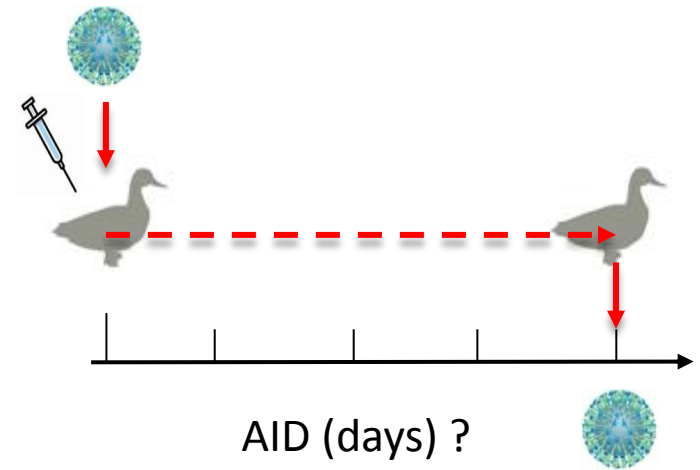- ✓ releasing experimentally-infected birds?

Indirect approach:

Combining experimental exposure
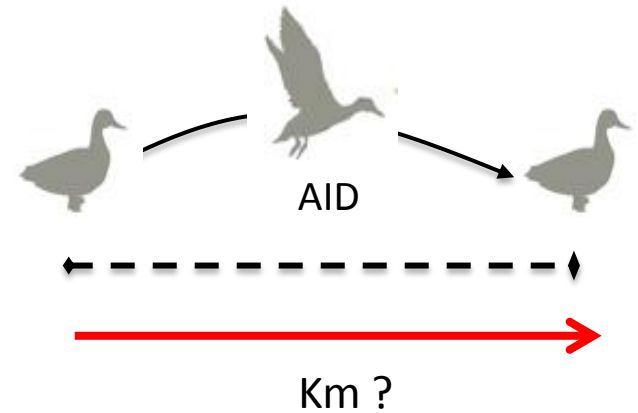
and satellite telemetry based data

Methodology

Step 1: Experimentally-infected wildfowl

→ Asymptomatic Infection Duration (AID)?

AID (days) ?

Step 2: Maximum distances covered by satellite-tracked birds during timeframes of asymptomatic infection?
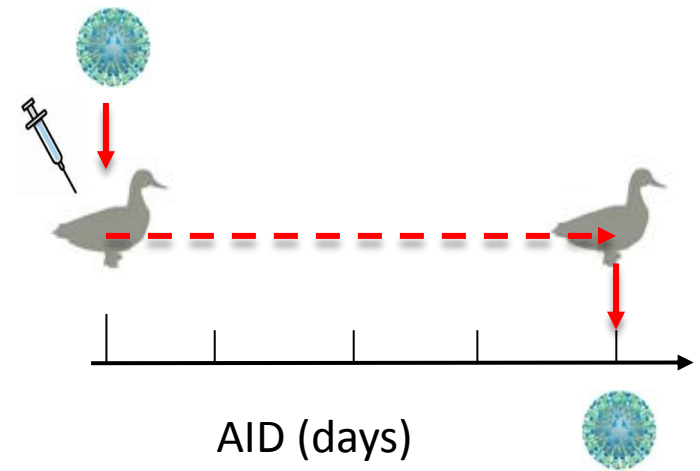
AID

Km ?

Step 1: Review of experimental infection studies of wildfowl with HPAI H5N1

Only wild species of duck, geese, swans:

→ 18 species, 135 birds*

Only Qinghai lineage viruses (clade 2.2)*

AID (days)

Brown et al. 2006; Brown et al. 2007; Brown et al. 2008; Kalthoff et al. 2008; Keawcharoen et al. 2008; Kwon et al. 2010

Step 1: Review of experimental infection studies of wildfowl with HPAI H5N1

Species*	No.	Age (months)	Treatment group†	Strains‡	Dose§ log$_{10}$	Viral excretion Infect %‡‡	Viral excretion Onset dpi	Viral excretion Duration days	Clinical response** Onset dpi	Clinical response** Sick/ Total	Clinical response** Dead/ Total	Clinical response** MDT dpi	AID†† days	R
Asymptomatic														
North. pintail	3	2·5–4	In	WS/Mg/05	6$_a$	100	1	1–2		0/3	0/3		2·5 (2–3)	1
Comm. teal	3	2·5–4	In	WS/Mg/05	6$_a$	100	1	2		0/3	0/3		3 (3–3)	1
	8	8–11	In	Tk/Tk/05	4$_b$	38	1	1–5		0/8	0/8		3·5 (2–6)	5
Eur. wigeon	8	8–11	In	Tk/Tk/05	4$_b$	50	1	1–2		0/8	0/8		2·5 (2–3)	5
Mallard	8	8–11	In	Tk/Tk/05	4$_b$	100	1	1–4		0/8	0/8		4 (2–5)	5
	3	3	In/Ct	Ck/Kr/06	6$_a$	100	1	2–3		0/3	0/3		3·5 (3–4)	6
Gadwall	8	8–11	In	Tk/Tk/05	4$_b$	88	1	1–6		0/8	0/8		4 (2–7)	5
Redhead	3	2·5–4	In	WS/Mg/05	6$_a$	100	1	1–4		0/3	0/3		3·5 (2–5)	1
Symptomatic														
Wood duck	3	2·5–4	In	WS/Mg/05	6$_a$	100	1	4–6	5	2/3	2/3	7·5	5·5 (5–6)	1
	20	3–4	In	WS/Mg/05	1·5–6$_a$	95	2	2–4	NA	18/20	18/20	5·5	5 (4–6)	2
Mandarin duck	3	2	In/Ct	Ck/Kr/06	6$_a$	100	1	5–6	4	1/3	1/3	5	6 (4–7)	6
Eur. pochard	7	8–11	In	Tk/Tk/05	4$_b$	100	1	2–5	3–6	4/7	1/7	4	3·5 (3–6)	5
Tufted duck	7	8–11	In	Tk/Tk/05	4$_b$	86	1	2–4	3·5	7/7	3/7	4	3·5 (1–4)	5
Ruddy sheld.	3	3	In/Ct	Ck/Kr/06	6$_a$	100	4	6	5	3/3	3/3	7	5 (5–5)	6
Bar-hd. goose	5	3	In/Ct	WS/Mg/05	6$_a$	100	1–2	5–8	3–7	5/5	2/5	6·5	4·5 (3–7)	3
Cack. goose	4	3	In/Ct	WS/Mg/05	6$_a$	100	1–3	4–6	3–7	4/4	3/4	6	5 (3–7)	3
Greylag goose	3	1·75	In/Ct	Ck/Kr/06	6$_a$	67	1	5–6	5–6	3/3	0/3		5·5 (5–6)	6
Black swan	5	1–1·5	In/Ct	WS/Mg/05	6$_a$	100	1	2–3	1–2	5/5	5/5	2·5	1·5 (1–2)	3
Trump. swan	5	1–1·5	In/Ct	WS/Mg/05	6$_a$	100	1	4–6	2	5/5	5/5	4·5	2 (2–2)	3
Whooper swan	4	1–1·5	In/Ct	WS/Mg/05	6$_a$	100	1	4–6	2–4	4/4	4/4	4	3 (2–4)	3
Mute swan	5	1–1·5	In/Ct	WS/Mg/05	6$_a$	100	1	3–7	5–7	5/5	5/5	6·5	6 (5–7)	3
	14	12–48	In/Ct/Px	WS/Gm/06	4–6$_a$	100	1–3	6	4–8	12/14	11/14	9	5·5 (3–8)	4
	3	1·75	In/Ct	Ck/Kr/06	6$_a$	100	1	3–5	3–4	3/3	3/3	4·5	3·5 (3–4)	6
Total 18 sp.	135	1–48	3	4	1·5–6	90	1–4	1–8	1–8	0–100	0–100	2·5–9	4 (1–8)	

Brown et al. 2006; Brown et al. 2007; Brown et al. 2008; Kalthoff et al. 2008; Keawcharoen et al. 2008; Kwon et al. 2010
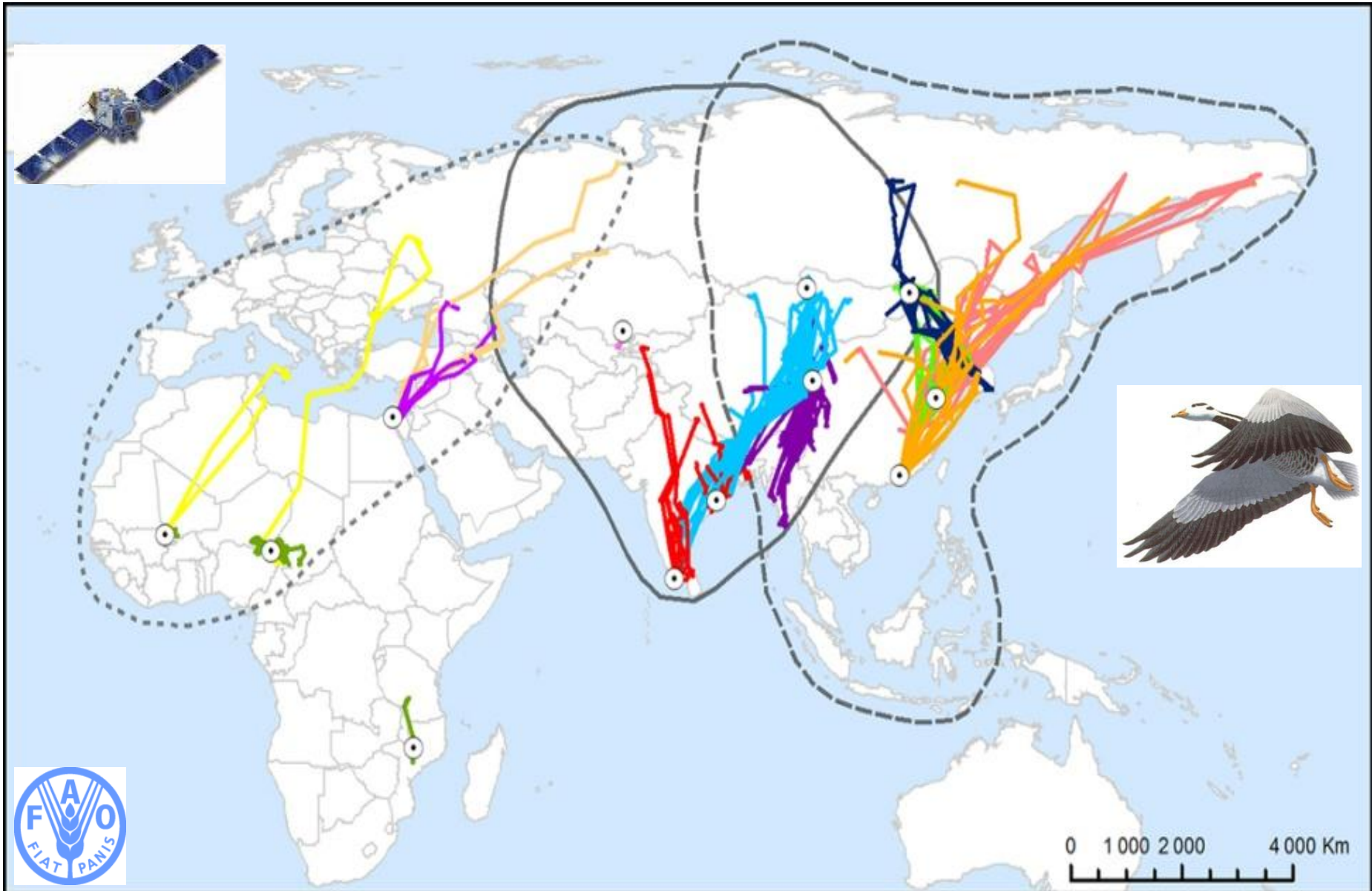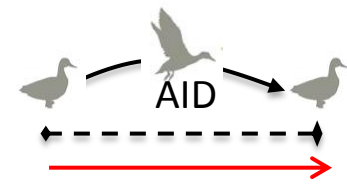
Step 1: Review of experimental infection studies of wildfowl with HPAI H5N1

➢ All species were receptive to infection

➢ Species heterogeneity in morbidity and mortality rates

➢ A period of asymptomatic infection in all infected birds:

  ✓ without any apparent clinical signs (6 species)

  ✓ before the onset of detectable clinical signs (12 species)

 → **Mean AID (min-max) = 4 days (1-8 days)**

Brown et al. 2006; Brown et al. 2007; Brown et al. 2008; Kalthoff et al. 2008; Keawcharoen et al. 2008; Kwon et al. 2010

Step 2: Movements of satellite-tracked birds during AID timeframes

A large-scale satellite telemetry data set

- ✓ International collaboration programme - FAO
- ✓ 228 birds - 19 species (ducks, geese, swans)
- ✓ over the main H5N1-affected regions
- ✓ some of the main candidate-vector species

(mallard, bar-headed goose, whooper swan)
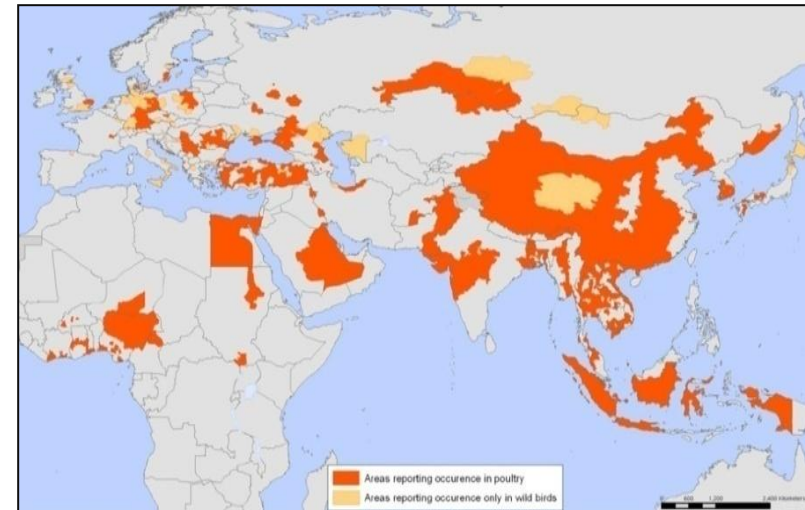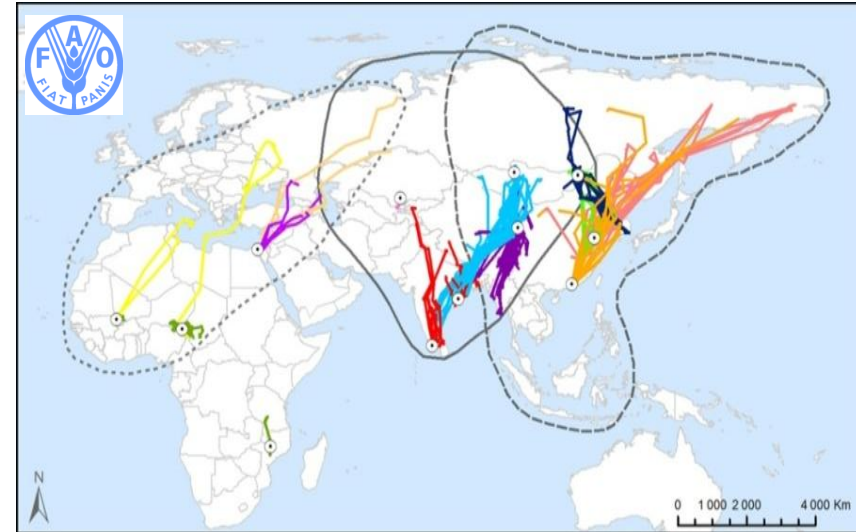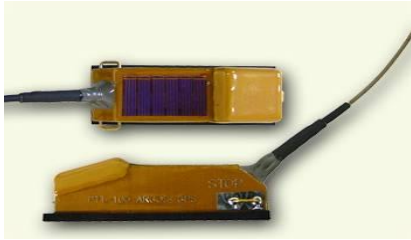
# Method: estimation of the maximum potential dispersal range

Maximum distance covered by a bird during every 4 day-timeframes (Dmax.4) ?

AID (4 days)
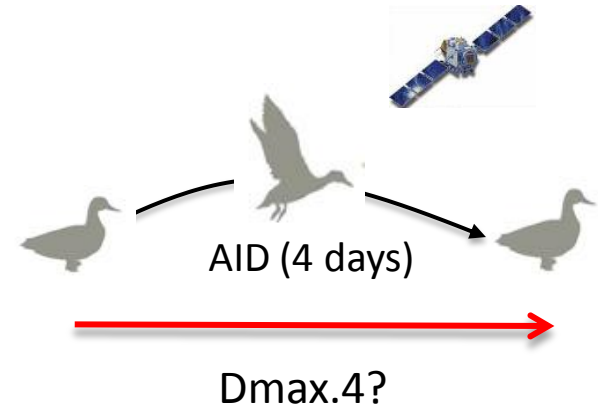
Dmax.4?

✓ calculated for each bird
✓ for each day, considering each location as a site and time of potential infection

Day post-infection (Dpi)

→ iterative process: sliding 4-day timeframe over the entire monitoring period

Dpi 1

Dpi 2

Dpi 3

Dpi 4

✓ for AID of 1, 4, 8 days
   → **Dmax.1, Dmax.4, Dmax.8**

Day-infection
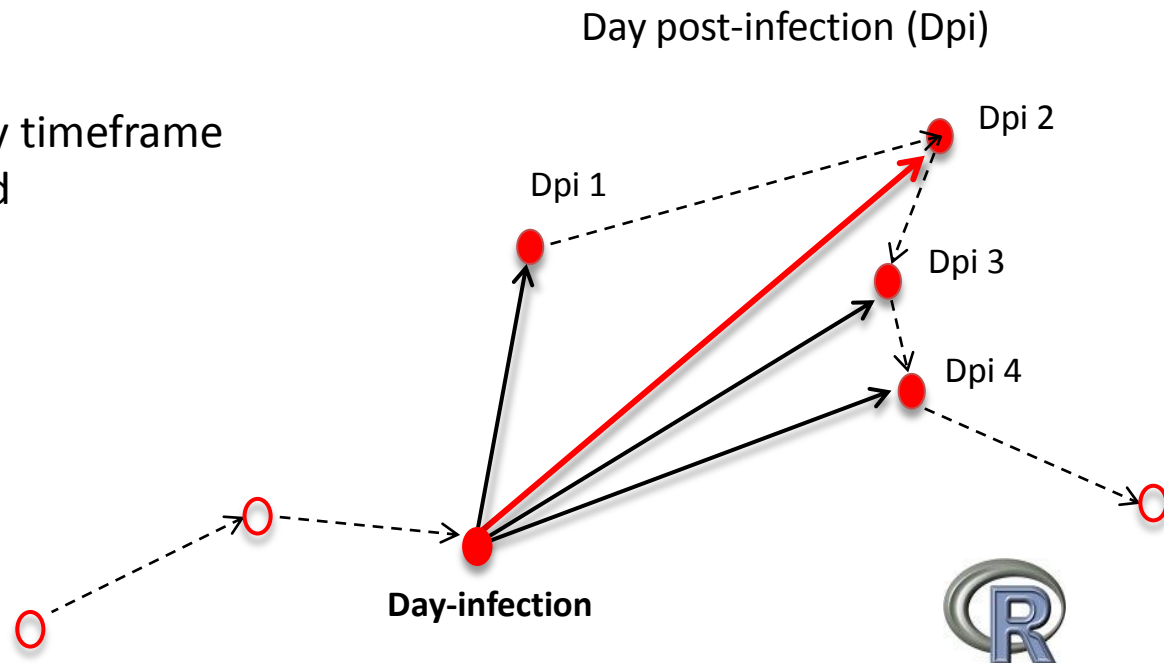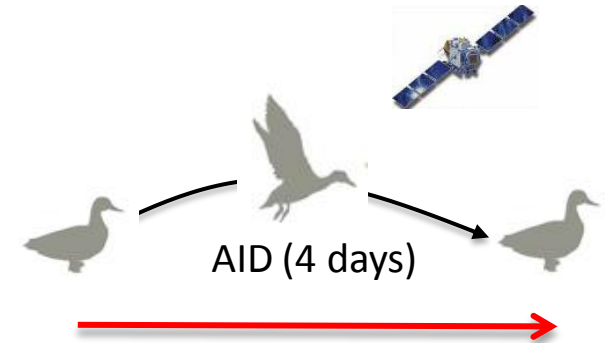
Results: maximum potential dispersal range

Mean maximum distances covered by migratory birds (satellite telemetry):

✓ Spring and fall migrations:

 ~300 to 1700 km* within the mean AID (4 days)

 up to 2900 km in some individuals

 ~100 to 1000 km* within min. AID (1 day)

AID (4 days)

✓ Outside migration or in non-migratory birds:

 Dmax4 <350 km*

→ Migratory wildfowl have the potential to disperse HPAI H5N1 virus over extensive distances
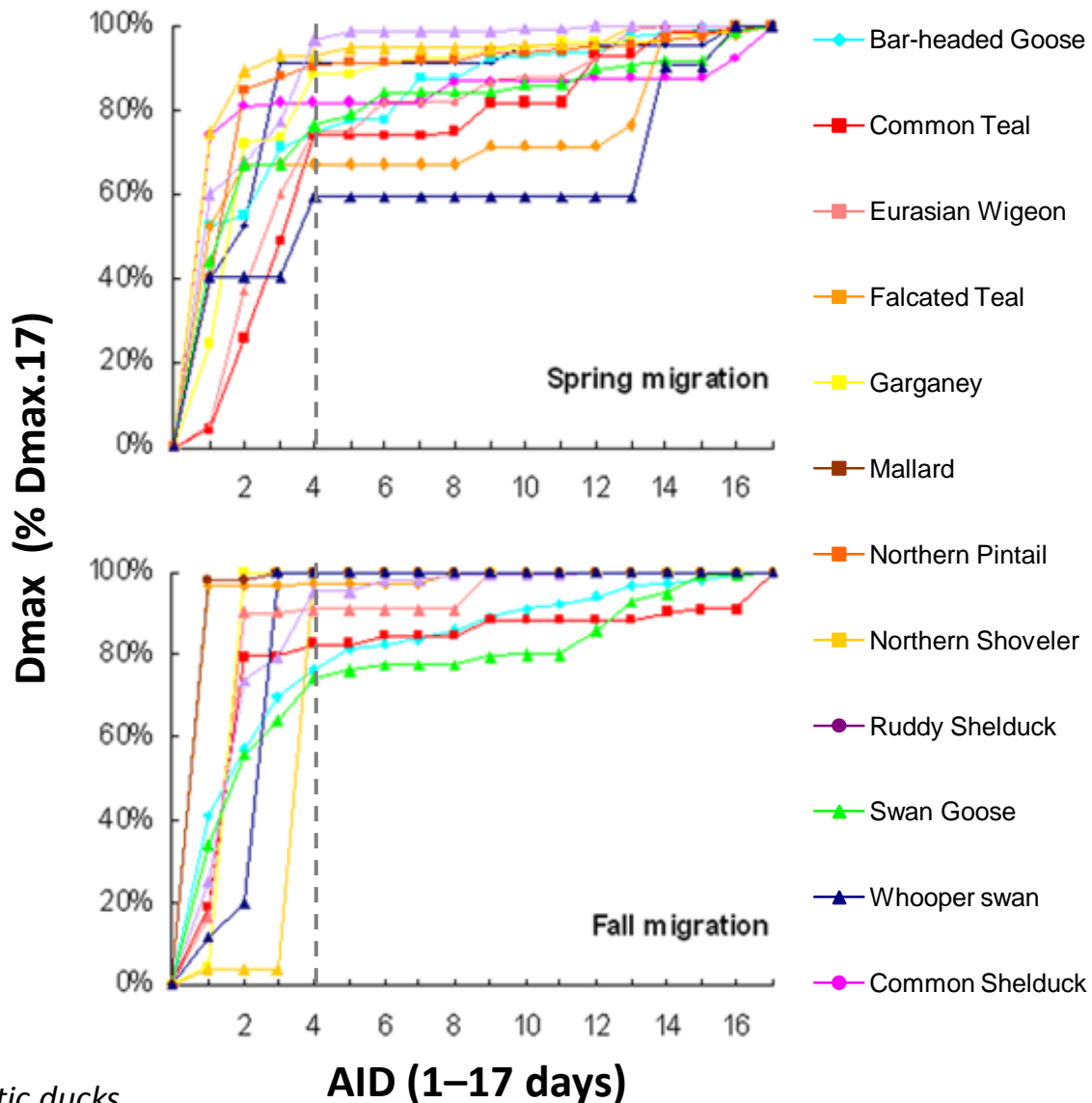
*on average per species

Results: maximum potential dispersal range

Dmax.4 ≈ Dmax.8

→ Plot Dmax ~ AID (1-17 days*)

→ A threshold in the maximum dispersal distance:

• ≥75 % of maximum distance in 17 days performed in 1-4 days

• no consecutive long-distance movements

Legend:
- Bar-headed Goose
- Common Teal
- Eurasian Wigeon
- Falcated Teal
- Garganey
- Mallard
- Northern Pintail
- Northern Shoveler
- Ruddy Shelduck
- Swan Goose
- Whooper swan
- Common Shelduck

Spring migration

Fall migration

Dmax (% Dmax.17)

AID (1–17 days)

17 days = longest H5N1 HPAI shedding in domestic ducks

Results: maximum potential dispersal range

Migration is sequential rather than continuous :

✓ completed in a few rapid long-distance flights

✓ interrupted by staging period > period of infection and shedding

→ Birds are unlikely to spread virus over several consecutive but interrupted long-distance movements

→ Potential for virus dispersal limited to a single long-distance movement (<2000 km)

Estimation of the potential dispersal rate

Proportion of days/year when an infection could result in a long-distance dispersal of HPAI H5N1 virus in the following days ?
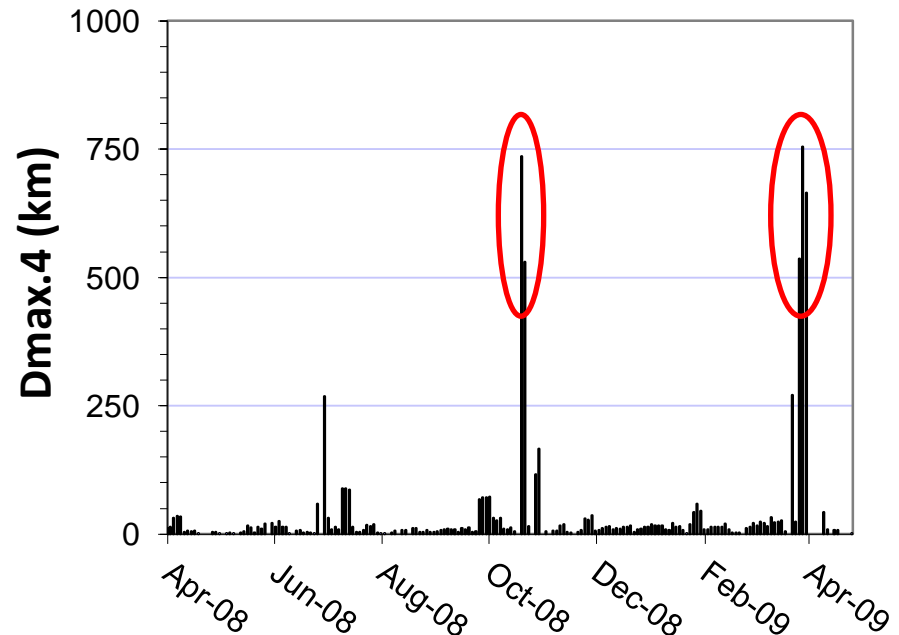
→ % of days/year with Dmax.4 $\geq$ 500 km?

→ a low individual dispersal rate:

✓ **potential for virus dispersal >500 km**
   = 5 to 15 days per year*

✓ restricted to the migration periods

Bar-headed goose: India ↔ China

*on average per species

Conclusion

1. **A potential for dispersal of HPAI H5N1 viruses over extensive distances**:

✓ All experimentally infected species showed a period of asymptomatic infection

✓ Long-distance movements were performed within timeframes compatible with the duration of asymptomatic infection

✓ Impact of infection on migration performance? migration-mediated immune changes?

Conclusion

2. A low individual likelihood for long-distance virus dispersal :

✓ Asymptomatic infection must coincide with timing of long-distance movements

→ Few long-distance movements per individual per year

✓ Migration is interrupted by staging periods > period of infection

→ Intercontinental virus dispersion likely require a relay transmission
→ Role of stop-over/congregation sites

Acknowledgements

Telemetry programme coordinated and funded by FAO
(contributions of the Governments of France, UK, of the Kingdom of Sweden, and of the Kingdom of Saudi Arabia)

French Ministry of Foreign Affairs – GRIPAVI project

Numerous ornithologists and veterinarians who participated to field operations