

UPDATE ON EPIDEMIOLOGY OF HPAI IN WILD BIRDS: VIRUS-HOST ECOLOGY

*Mauro Delogu, Laboratory of Pathogens' Ecology, Wildlife and Exotic Animal Service,
Department of Veterinary Medical Sciences, Bologna University, Italy - Email
mauro.delogu@unibo.it*

*Maria Alessandra De Marco, Wildlife Service, ISPRA Institute for Environmental
Protection and Research, Italy - E-mail mariaalessandra.demarco@isprambiente.it*

ECOLOGY OF **HPAIVs** IN WILD BIRDS: WHAT IS CHANGING?

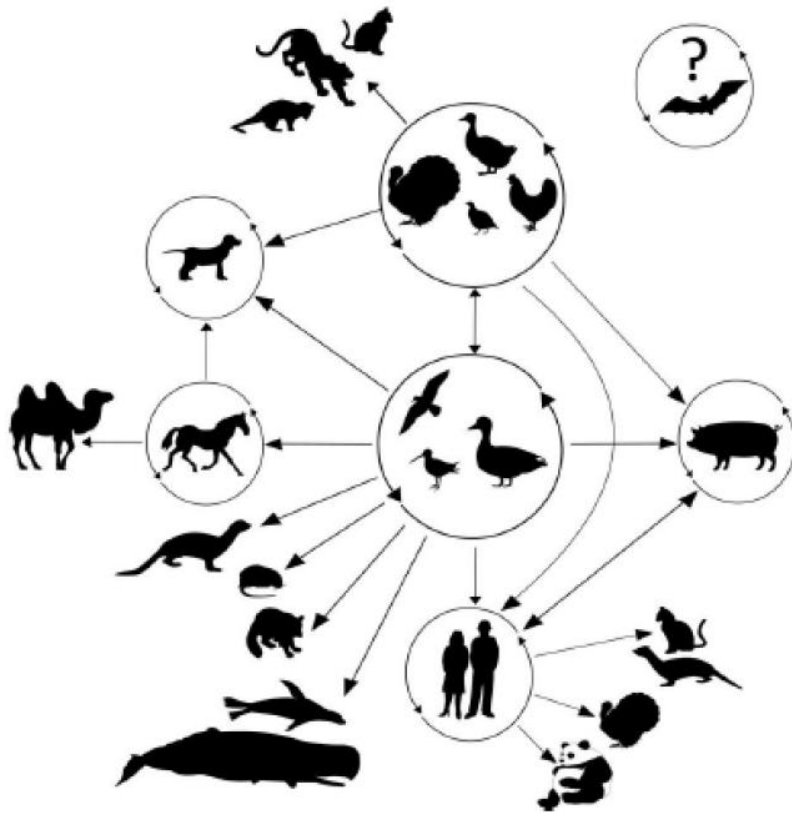


Figure 1. Examples of Influenza A Virus Interspecies Transmission.

Reprinted from: Ecology of Avian Influenza Viruses in Siberia. In: Tabitha Robbins (Ed.) Siberia, ISBN: 978-1-63485-414-6, pp. 83-160, (2016) Maria Alessandra De Marco, Kirill Sharshov, Marina Gulyaeva, Mauro Delogu, Lorenzo Ciccarese, Maria Rita Castrucci and Alexander Shestopalov. Copyright © 2016 by Nova Science Publishers Inc. Reprinted with permission from Nova Science Publishers Inc.

FIRST DESCRIPTION:

HP H5N3 AIV that killed over 1,300 common terns in 1961 in South Africa (Becker, 1966, *J. Hyg.*, 64, 309-320)



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ORIGIN ?

FORTY YEARS LATER: H5N1 Gs/GD/1/1996 LINEAGE

After its first emergence in poultry in 1997, in 2002 the **HP H5N1 virus** re-emergence in South-East Asia in poultry, including waterfowl species, and it was also reported in **wild bird species** (Greater Flamingo, Little Egret, Grey Heron, Black-headed gull, feral pigeon, Tree Sparrow) (Ellis et al., 2004, *Avian Pathol.*, 33, 492-505; Sturm-Ramirez, et al., 2004, *J. Virol.*, 78, 4892-4901).

Greater Flamingo



Image by Bernard Spragg - [CC0 1.0](https://creativecommons.org/licenses/by/4.0/)

Little Egret



Image by gilgit2 - [CC BY-SA 2.0](https://creativecommons.org/licenses/by-sa/4.0/)

Tree Sparrow

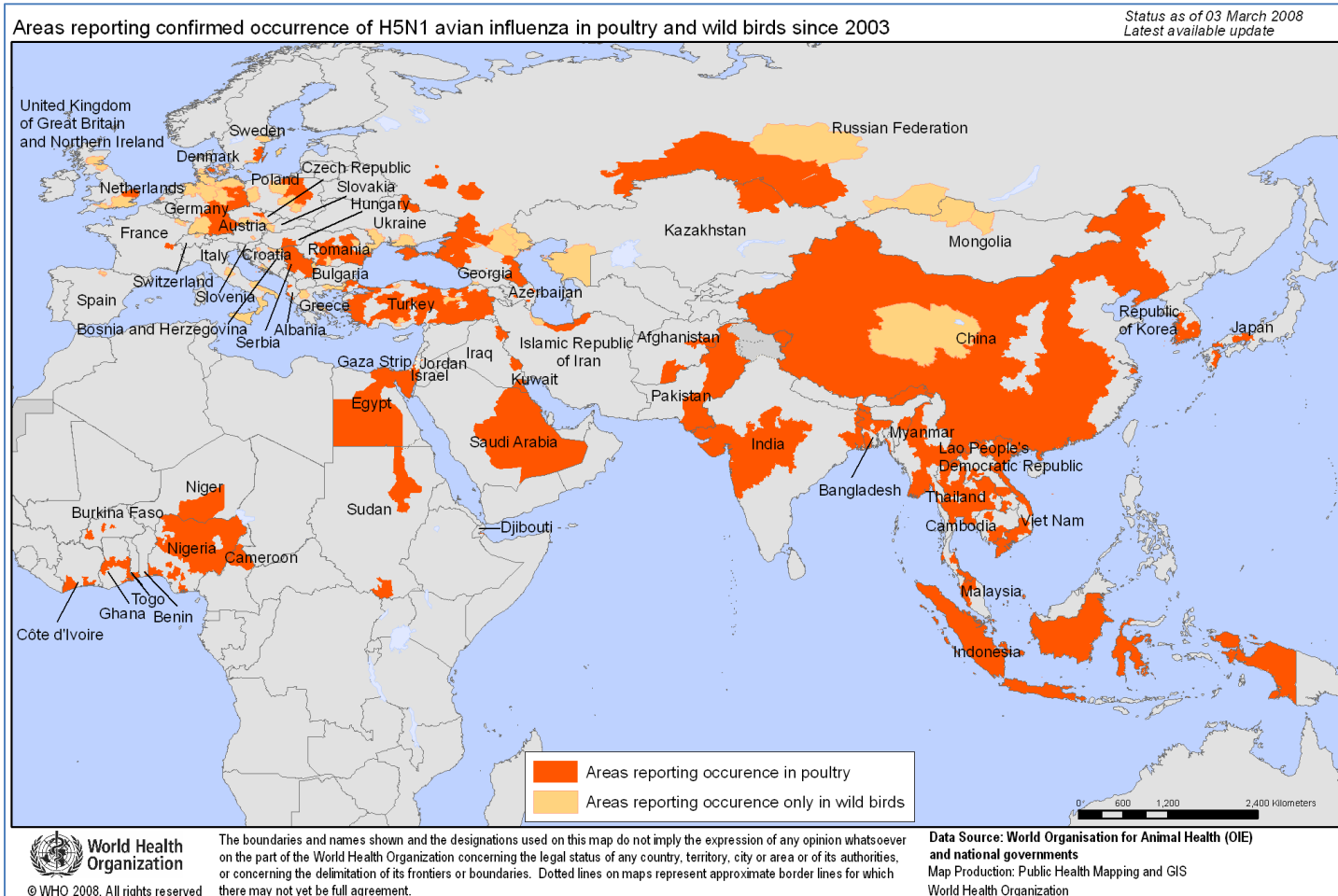


Image by hedera.baltica - [CC BY-SA 2.0](https://creativecommons.org/licenses/by-sa/4.0/)

Between **late 2003** and **early 2004**, the **HP H5N1** virus started its progressive spread among domestic and **wild birds** throughout areas of **Eastern and South-East Asia**, later involving, as H5 virus clade 2.2, the **Asian portion of Russia, Europe, the Middle East, and Africa** (Olsen et al., 2006, *Science*, 312, 384–388)

HP H5N1 GLOBAL SPREAD IN POULTRY AND WILD BIRDS

New scenario for evaluating the potential involvement of migratory avifauna in spreading and maintaining HPAIVs in natural habitats



INNOVATIVE STUDIES BASED ON AN ECOLOGICAL APPROACH: BIRD MOVEMENTS AND AIV SPREAD

INFLUENZA

REVIEW

Global Patterns of Influenza A Virus in Wild Birds

Björn Olsen, Vincent J. Munster, Anders Wallensten, Jonas Waldenström, Albert D. M. E. Osterhaus, Ron A. M. Fouchier

(Olsen et al., 2006, *Science*, 312, 384–388)



Image by davidyuweb - [CC BY-NC 2.0](#)

The **Mallard**, the most numerous Holarctic waterfowl species, is widely distributed over the whole Northern Hemisphere. Migratory mallard populations often do not exhibit clearly defined routes (Kraus et al., 2011, *BMC Genet.*, 12, 99 <https://doi.org/10.1186/1471-2156-12-99>)

“The ecology, epidemiology, genetics, and evolution of **pathogens** cannot be fully understood without taking into account the ecology of **their hosts**”

HOST SPECIES DISTRIBUTION

- Areas in which species breed and are absent during the winter
- Areas in which species are present around the year
- Areas in which species are only present in winter and do not breed

Blue-winged Teal



Image by Gregory 'Slobirdr' Smith - [CC BY-SA 2.0](#)

Garganey



Image by Le poidesans - [CC BY 2.0](#)

Both **Blue-winged Teal** and **Garganey** are long distance migratory duck species in the New World and Old World, respectively

MORE RECENTLY, reassortant H5 viruses of the **Gs/GD lineage**, having **N2, N3, N6 or N8** genes, emerged in **South-East Asia**. Among these, the **H5N8 HPAIV** (lineage H5 clade **2.3.4.4**), emerged in **late 2013** in **China**, spreading in **2014** to **South Korea** (Dally et al., 2015, *PeerJ*, 3:e934, doi: 10.7717/peerj.934; Jeong et al., 2014, *Vet. Microbiol*, 173, 249-257). Three genetically distinct subgroups emerged and subsequently spread along different flyways during **fall 2014** into **Europe, North America, and East Asia**, respectively.

Intercontinental Spread of Asian-Origin H5N8 to North America through Beringia by Migratory Birds (Lee et al., 2015, *J Virol.*, 89(12):6521-4)

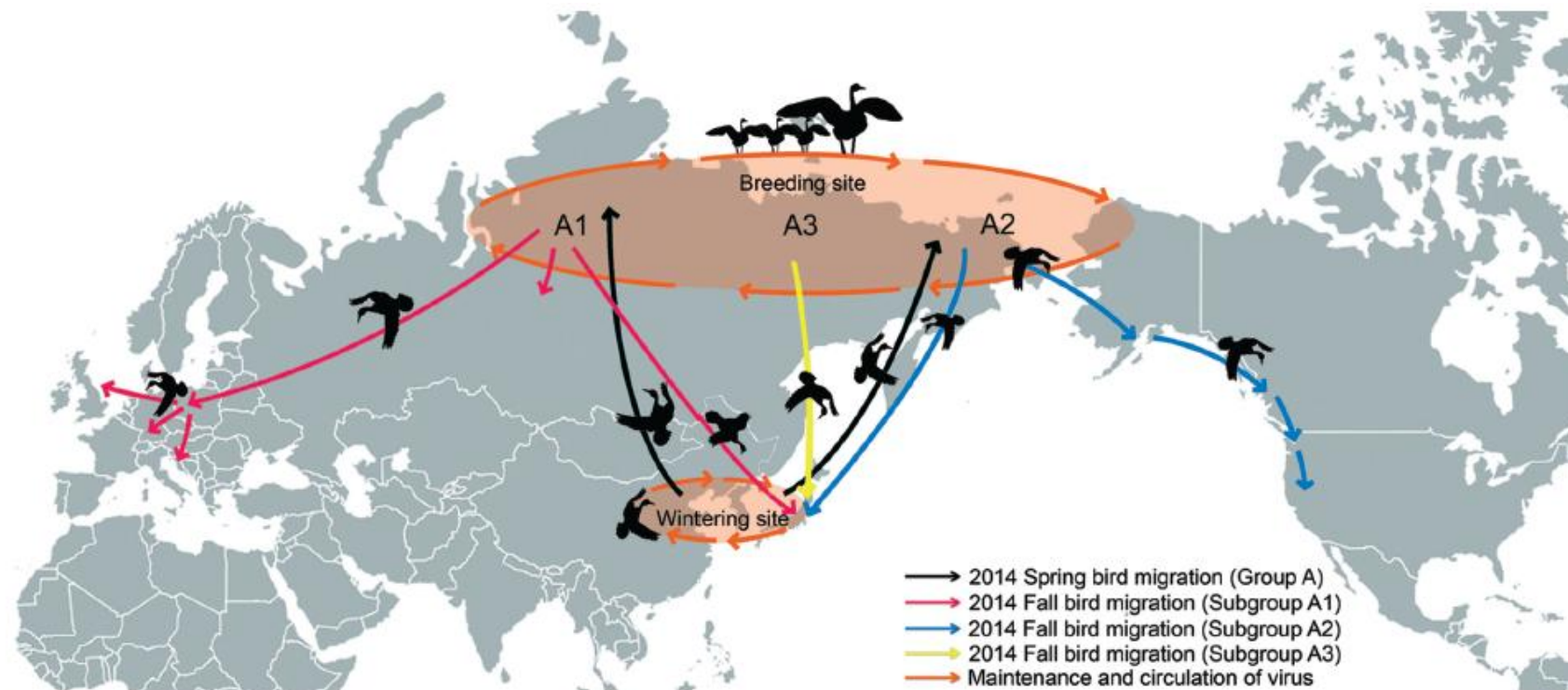


FIG 2 Geographic map showing the movement of H5N8 HPAIV in Asia, Europe, and North America in relation to regional waterfowl migration routes. The map, by Dmthoth, is from Wikipedia Commons (http://commons.wikimedia.org/wiki/File:Blank_Map_Pacific_World.svg).

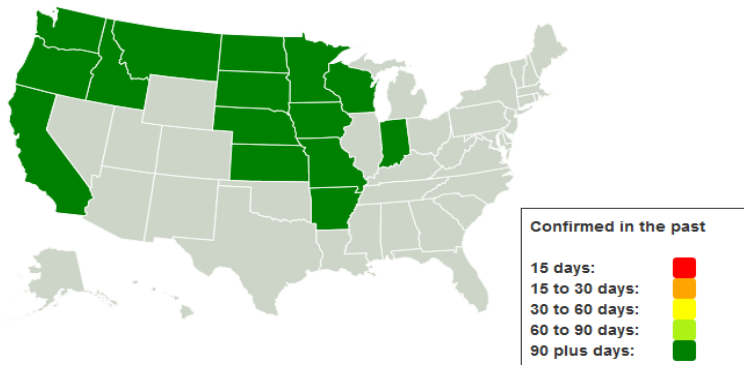
ONCE AGAIN, A NEW SCENARIO EMERGED:

Role for migratory wild birds in the global spread of avian influenza H5N8

The Global Consortium for H5N8 and Related Influenza Viruses, *Science*, 2016, 354(6309), 213-217

HP H5 AIVs IN POULTRY IN NORTH AMERICA

Update on Avian Influenza Findings
Poultry Findings Confirmed by USDA's National Veterinary Services Laboratories



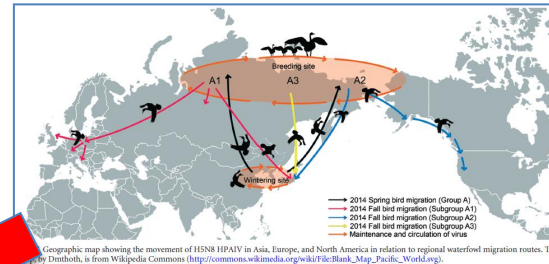
223
Detections Reported

48,091,293
Birds Affected

12/19/14
First Detection Reported

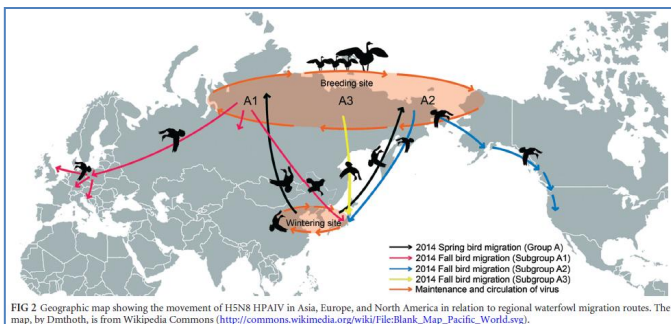
6/17/15
Last Detection Reported

- **H5N8 (clade 2.3.4.4)** virus, following the 2014 outbreak in poultry in South Korea, **rapidly spreads worldwide in 2014–2015**
- **long-distance migratory birds —ducks, swans, and geese** that meet at their Arctic breeding grounds— can play a **major role** in the **global spread** of AIVs
- **HA of clade 2.3.4.4** creates reassortment events with multiple **NA subtypes (H5Nx viruses)**



HPAI H5 infections have been reported in U.S. domestic poultry (backyard and commercial flocks), captive wild birds, and **wild birds** by the USDA and the U.S. DOI. HPAI H5 detections began in **December 2014** and continued into **mid-June 2015**.

WHAT HAPPENED IN NORTH AMERICA IN WILD BIRD POPULATIONS?



WHAT HAPPENED IN NORTH AMERICA IN WILD BIRD POPULATIONS?

The enigma of the apparent disappearance of Eurasian highly pathogenic H5 clade 2.3.4.4 influenza A viruses in North American waterfowl

PNAS | August 9, 2016 | vol. 113 | no. 32 | 9033–9038

Scott Krauss^a, David E. Stallknecht^b, Richard D. Slemons^c, Andrew S. Bowman^c, Rebecca L. Poulson^b,
Jacqueline M. Nolting^c, James P. Knowles^a, and Robert G. Webster^{a,1}

AVIAN DISEASES 63:366-370, 2019

Research Note—

Clade 2.3.4.4 H5 North American Highly Pathogenic Avian Influenza Viruses Infect, but Do Not Cause Clinical Signs in American Black Ducks (*Anas rubripes*)

Erica Spackman, Diann J. Prosser, Mary Pantin-Jackwood, Christopher B. Stephens, and Alicia M. Berlin

H5 HP AIVs APPARENTLY DISAPPEARED, DESPITE THE PRESENCE OF WILD BIRD SPECIES THAT EXPERIMENTALLY HAVE SHOWN THE POTENTIAL TO BECOME EFFICIENT RESERVOIR

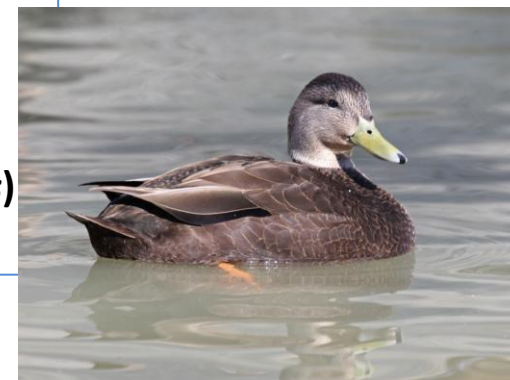


Image by DickDaniel (<http://carolinabirds.org/>)
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HP H5N8 INTRODUCTION IN EUROPE

On 6 November 2014, Germany has become the first European country to report an outbreak of HPAI caused by an H5N8 virus genetically similar to one spreading in the Republic of Korea since January.

The virus causes high mortality in poultry.

The route of introduction into Germany remains unclear, but the long-distance spread from Asia to Europe indicates that wild birds may play a role.

FAO emphasizes the need for continued vigilance worldwide and heightened efforts on farms to prevent contact between poultry and wild birds.

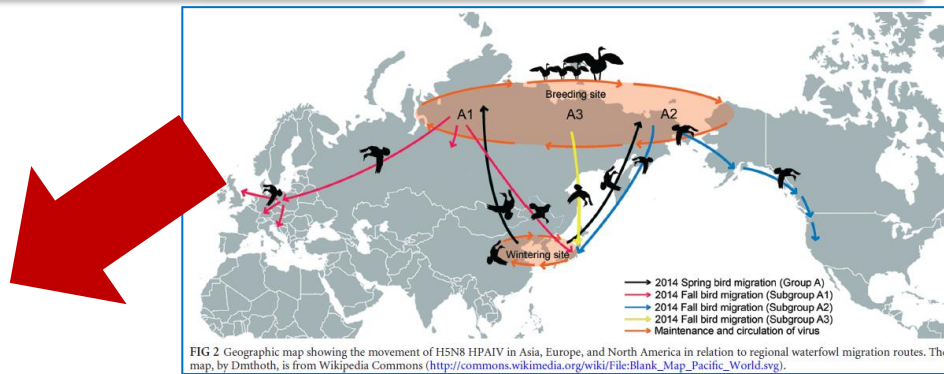
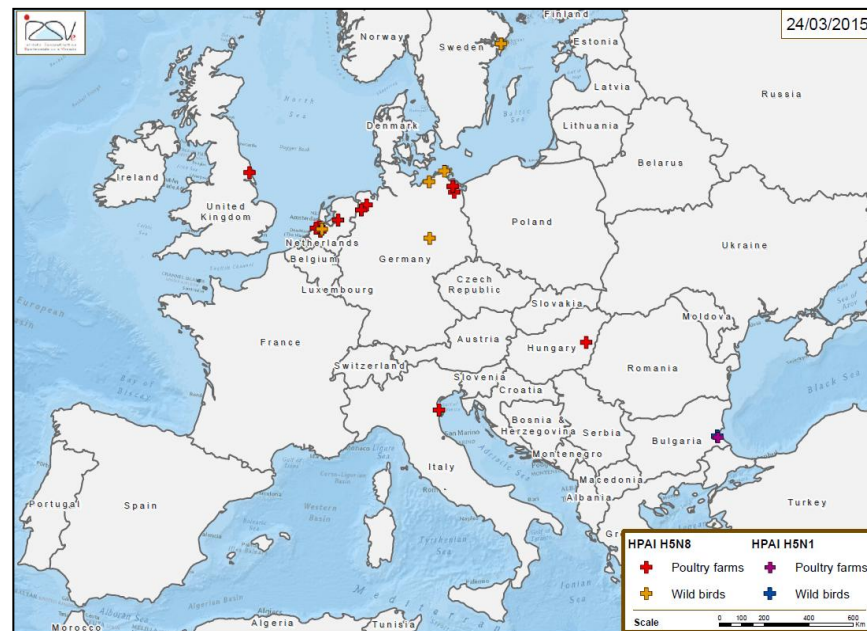


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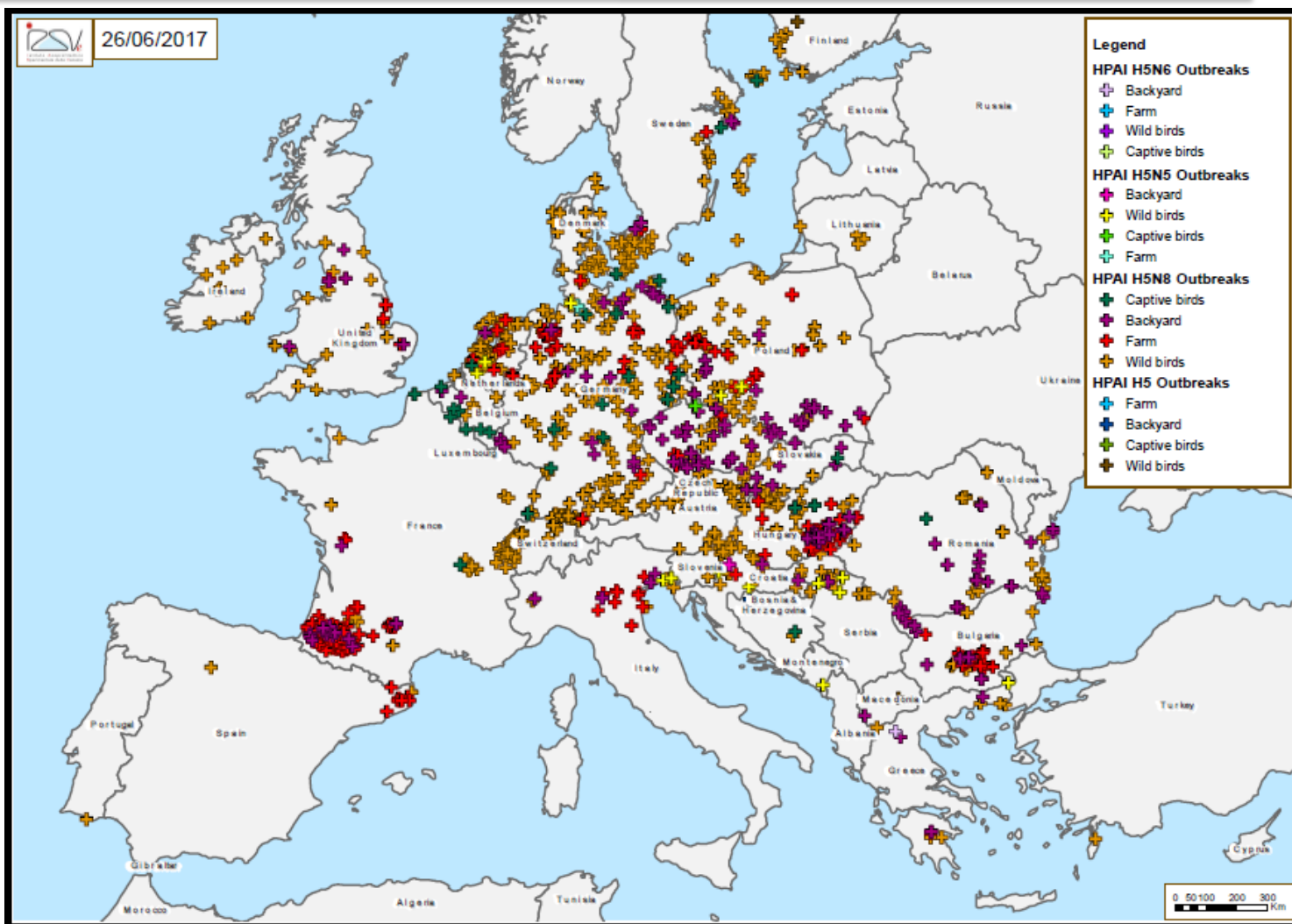
http://www.fao.org/ag/againfo/home/en/news_archive/2014_A-H5N8_detected_in_Europe.html

WHAT HAPPENED IN EUROPE IN WILD BIRD POPULATIONS?

Wild birds: HPAI H5N8 HPAI H5N1

2016/2019 – H5 HP H5 SPREAD IN POULTRY AND WILD BIRDS IN EUROPE

Since the **beginning of November 2016**, many European countries have been affected by cases of HPAI caused by H5N8, H5N5, H5Nx subtype of viruses.



<https://izsvenezie.com/documents/reference-laboratories/avian-influenza/europe-updates/HPAI/2016-1/map.pdf>

Wild birds :  HPAI H5N6

 HPAI H5N5

 HPAI H5N8

 HPAI H5



HP H5 Number of outbreaks occurred in each Country

**TOTAL IN WILD
BIRDS:
973 outbreaks**

(updated 18/06/2018)

Country	Farms	N.D.	Backyard	Wild birds	Captive birds	Total
Austria	1		1	26	1	29
Belgium			2	4	11	17
Bosnia-Erzegovina			1	1	1	3
Bulgaria	52		20	13	2	87
Croatia	1		10	11		22
Denmark			1	51	1	53
Finland				16	1	17
France	395	29	25	52	3	504
Germany	68		24	184	16	292
Greece	1		5	10		16
Ireland				9		9
Italy	66		20	14		100
Lithuania				5		5
Luxembourg	1		3			4
Montenegro				1		1
Netherlands	9			57	1	67
Poland	38		26	71		135
Portugal				1		1
United Kingdom	7		6	21		34
Czech Rep.	6		33	33	1	73
Rep of Macedonia			1	1		2
Romania			46	89	1	136
Serbia			4	21		25
Slovakia			9	59	1	69
Slovenia				21		21
Spain	10			2		12
Sveden	2		3	37	1	43
Svitzerland				94		94
Ungary	214		26	69	2	311
Total	871	29	266	973	43	2182

HP H5

Number of birds involved in each Country

TOTAL IN WILD

BIRDS:

3,081 birds involved

(updated 18/06/2018)

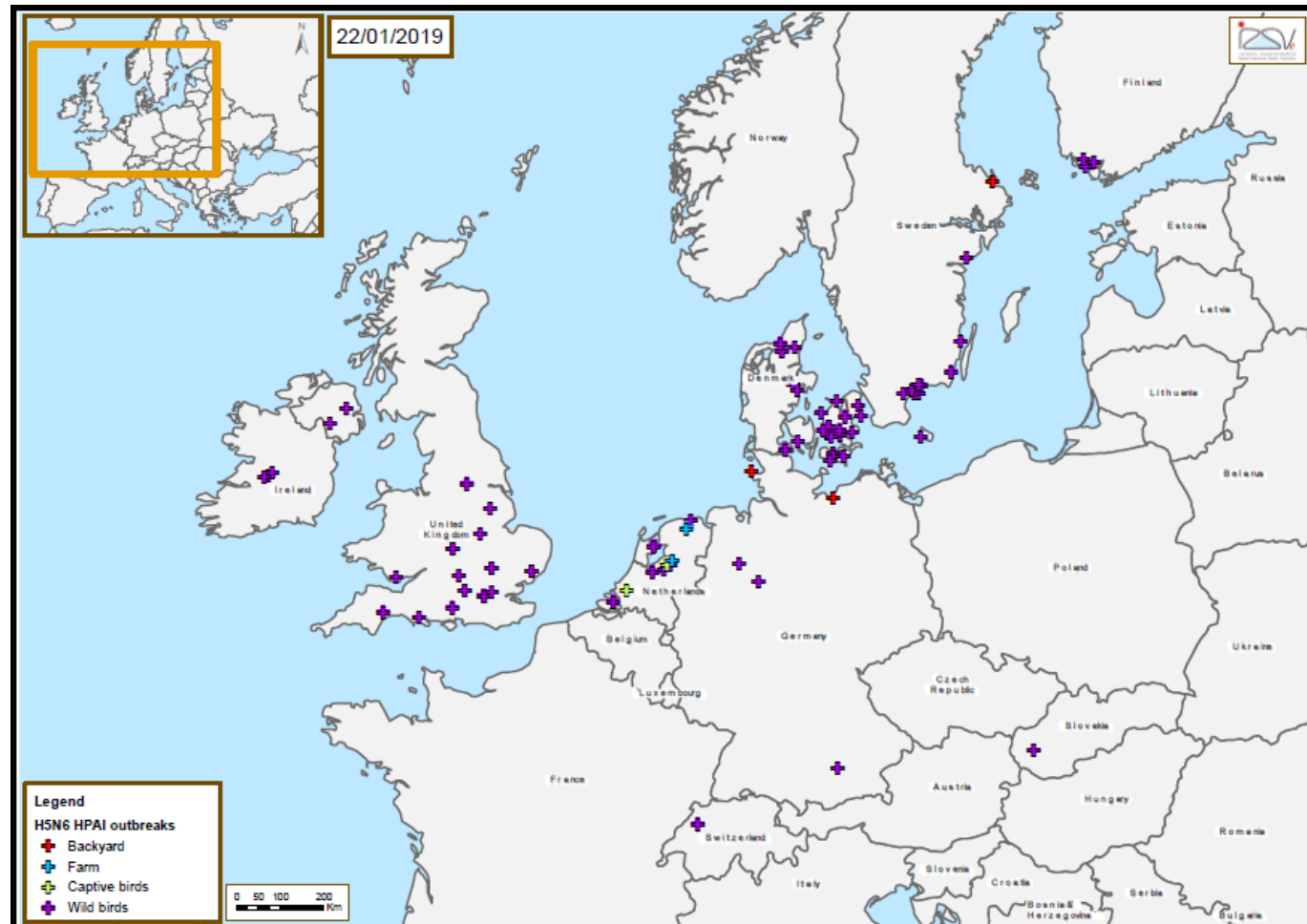
Stato	Farms	Backyard	Wild birds	Captive birds	Total
Austria	1.150	108	150	2	1.410
Belgium		5.019	6	458	5.483
Bosnia-Erzegovina		148	1	2	151
Bulgaria	771.905	3.256	23	1.010	776.194
Croatia	927	662	39		1.628
Denmark		69	82	8	159
Finland			19	150	169
France	1.471.247	1.183	80	90	1.472.600
Germany	1.198.777	1.710	770	1.171	1.202.428
Greece	28.000	315	13		28.328
Ireland			12		12
Italy	2.743.831	6.764	30		2.750.625
Lithuania			13		13
Luxembourg	681	182			863
Montenegro			1		1
Netherlands	217.425		381	4	217.810
Poland	1.062.648	2.262	239		1.065.149
Portugal			1		1
United Kingdom	126.031	152	69		126.252
Czech Rep.	77.308	3.018	41	9	80.376
Rep of Macedonia		438	2		440
Romania		2.376	161	25	2.562
Serbia		289	70		359
Slovakia		366	261	4	631
Slovenia			268		268
Spain	28.330		3		28.333
Sveden	260.000	60	53	46	260.159
Svizzera			136		136
Ungary	2.700.246	3.159	157	4	2.703.566
Total	10.688.506	31.536	3.081	2.983	10.726.106

2017/2019 – H5N6

Since the beginning of **December 2017**, **Northern Europe** has been affected by outbreaks of HPAI caused by an **H5N6 subtype virus**.

The outbreaks mainly involved **wild birds** belonging to the families of the Anatidae, Accipitridae and Laridae.

So far, the mostly affected countries have been **Denmark, Finland, Ireland, Sweden, Slovakia, The Netherlands, the United Kingdom, Germany and Switzerland**.



<https://izsvenezie.com/documents/reference-laboratories/avian-influenza/europe-updates/HPAI/2017-1/map.pdf>

Wild birds:  HPAI H5N6

Table 3: Cases of HPAI A(H5N6) infection in free-living wild birds, ordered by country and species, occurred from 16 November 2017 to 15 February 2018 and reported to OIE (OIE, online)

OIE report no.	Country	No. of events	Species	No. of events in which the species was involved	No. of cases/event	Total no. of cases
26065	Denmark	1	White-tailed eagle	1	1	1
25844	Germany	1	Unidentified	1	1	1
25927	Ireland	1	White-tailed eagle	1	1	1
25986	Sweden	1	White-tailed eagle	1	1	1
25551	Switzerland	1	Mute swan	1	1	1
25786	The Netherlands	5	Black-headed gull	1	1	1
			Great black-backed gull	1	1	1
			Mute swan	4	1, 1, 4, 6	12
25963	United Kingdom	12	Canada goose	1	1	1
			Common moorhen	1	1	1
			Common pochard	1	1	1
			Great black-backed gull	1	6	6
			Great crested grebe	1	1	1
			Greylag goose	1	7	7
			Herring gull	1	1	1
			Mallard	3	1, 2, 8	11
			Mew gull	1	1	1
			Mute swan	6	1, 1, 1, 2, 5, 15	25
			Tufted duck	4	1, 1, 5, 5	12
			Unidentified	2	2, 3	5
Total	(7)	22	(13)	-	-	91

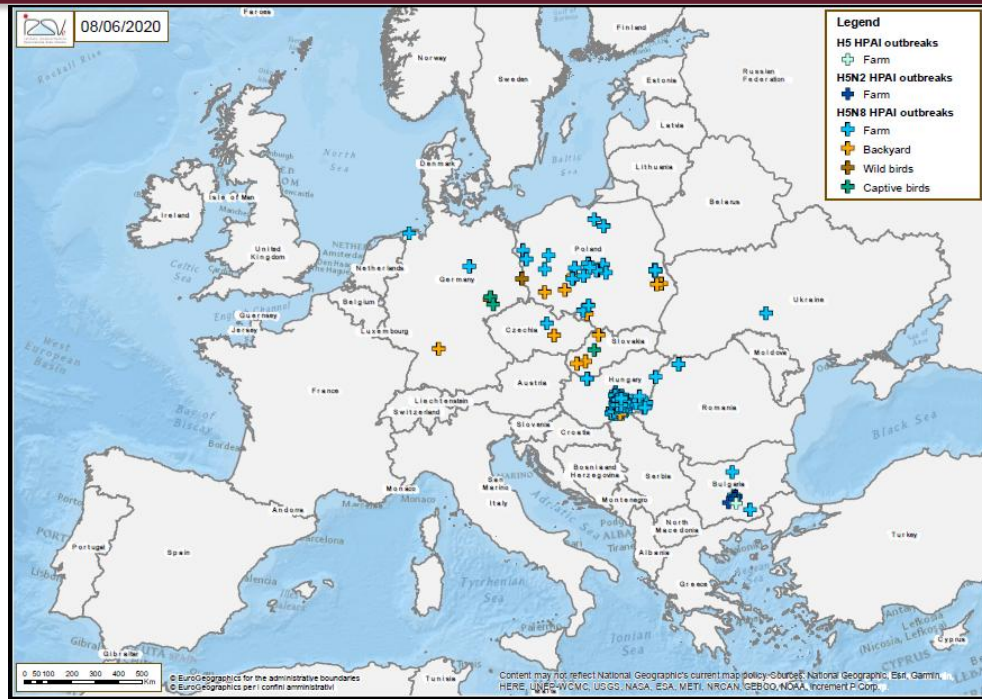
H5N6 HPAIV Bird Families involved between Nov. 2017-Feb. 2018



2019/2020 – H5N8

Since the **end of December 2019** some outbreaks of HPAI caused by **H5N8 subtype** have been reported in Europe.

Wild birds:  HPAI H5N8



<https://izsvenezie.com/documents/reference-laboratories/avian-influenza/europe-updates/HPAI/2019-1/map.pdf>

Sub-Saharan Africa and Eurasia Ancestry of Reassortant Highly Pathogenic Avian Influenza A(H5N8) Virus, Europe, December 2019

Edyta Świątoń, Alice Fusaro, Ismaila Shittu, Krzysztof Niemczuk, Bianca Zecchin,
Tony Joannis, Francesco Bonfante, Krzysztof Śmietanka, Calogero Terregino

2019/2020 – H5N8: ONLY THREE POSITIVITIES WERE REPORTED IN WILD BIRDS

Eurasian Sparrowhawk



Image by gilgit2 - [CC BY-SA 2.0](#)

or

Northern Goshawk

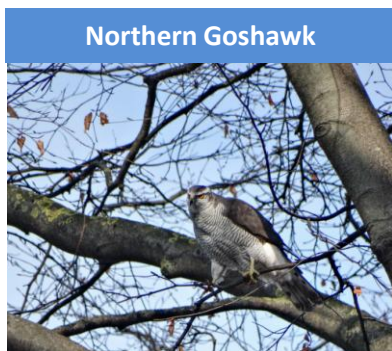


Image by Jevgenijs Slihto - [CC BY 2.0](#)

1) Hawk
Poland, 7 January 2020

**WHAT IS HAPPENING IN EUROPE
IN WILD BIRD POPULATIONS?**

Sub-Saharan Africa and Eurasia Ancestry of Reassortant Highly Pathogenic Avian Influenza A(H5N8) Virus, Europe, December 2019

Edyta Świątoń, Alice Fusaro, Ismaila Shittu, Krzysztof Niemczuk, Bianca Zecchin,
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Emerging Infectious Diseases • www.cdc.gov/eid • Vol. 26, No. 7, July 2020



Image by NDomer73 i - [CC BY-NC-ND 2.0](#)

2) Greater White-fronted Goose
Germany, 19 January 2020

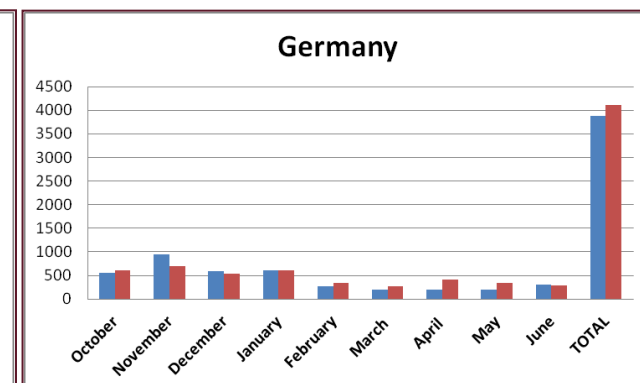
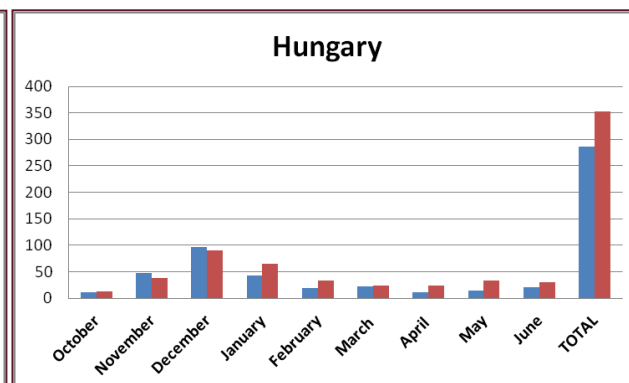
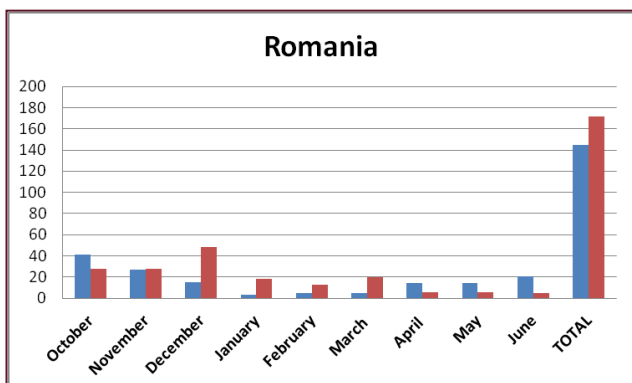
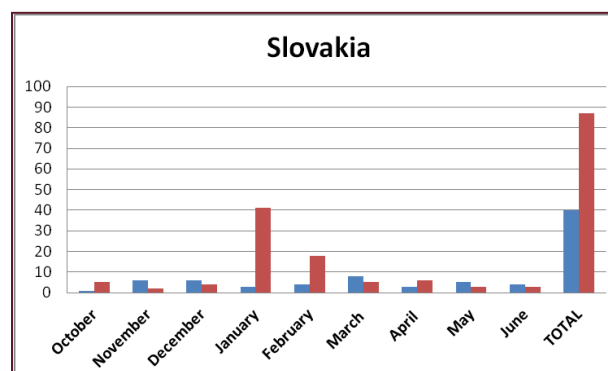
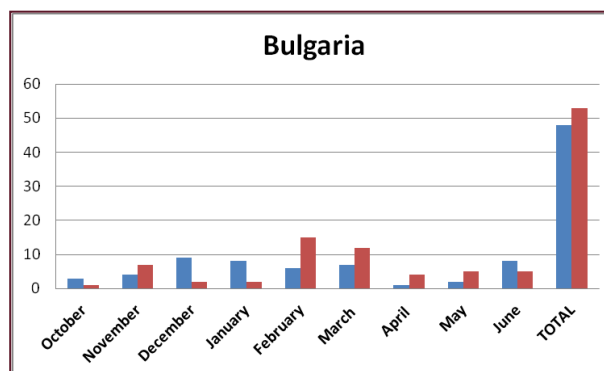
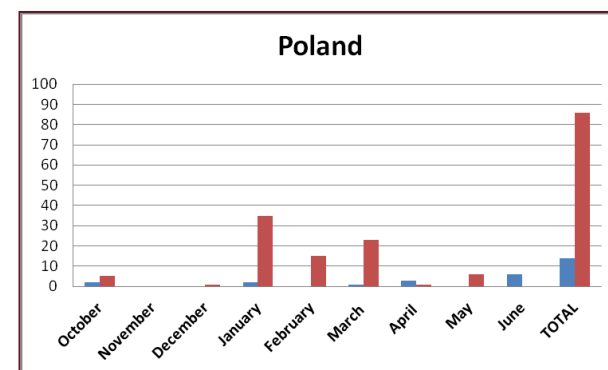
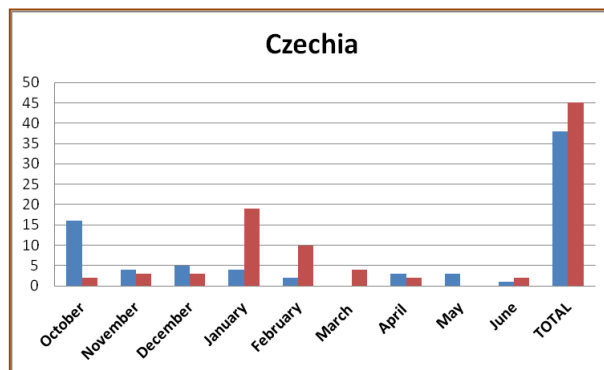


Image by Agustín Povedano -
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3) Common Buzzard
Germany, 11-12 March 2020

AVIAN INFLUENZA SURVEILLANCE IN WILD BIRDS: COMPARABLE SAMPLE SIZES

(DATA KINDLY PROVIDED BY EFSA)



(1st slide). FIFTY WILD BIRD SPECIES TARGETED FOR PASSIVE SURVEILLANCE OF H5 HPAI IN THE EU (from EFSA-ECDC-EURL scientific report AVIAN INFLUENZA OVERVIEW September – November 2017)

Family	Subfamily, tribe, or genus	Species	% positive (no. positive/no. tested)
Ducks, geese, and swans (Anatidae)	Diving ducks (Aythyini)	Tufted duck (<i>Aythya fuligula</i>)	33.4% (338/1011)
		Greater scaup (<i>Aythya marila</i>)	12.7% (9/71)
		Common pochard (<i>Aythya ferina</i>)	11.4% (26/228)
		Red-crested pochard (<i>Netta rufina</i>)	0.9% (1/112)
	Dabbling ducks (Anatinae)	Northern pintail (<i>Anas acuta</i>)	5.4% (3/56)
		Eurasian wigeon (<i>Anas penelope</i>)	3.7% (8/219)
		Gadwall (<i>Anas strepera</i>)	1.7% (3/179)
		Mallard (<i>Anas platyrhynchos</i>)	0.5% (96/20672)
	Sea ducks (Mergini)	Eurasian teal (<i>Anas crecca</i>)	0.4% (5/1145)
		Goosander (<i>Mergus merganser</i>)	6.4% (7/109)
		Common goldeneye (<i>Bucephala clangula</i>)	5.7% (3/53)
		Smew (<i>Mergus albellus</i>)	5.0% (1/20)
	Shelducks and sheldgeese (Tadorninae)	Common eider (<i>Somateria mollissima</i>)	1.3% (3/228)
		Common shelduck (<i>Tadorna tadorna</i>)	0.5% (1/218)
		Egyptian goose (<i>Alopochen aegyptiacus</i>)	0.4% (1/234)
	True geese (<i>Anser</i> , <i>Branta</i> , <i>Chen</i>)	Lesser white-fronted goose (<i>Anser erythropus</i>)	13% (3/23)
		Greylag goose (<i>Anser anser</i>)	3.5% (68/1968)
		Taiga bean Goose (<i>Anser fabalis</i>)	2.8% (4/143)
		Canada goose (<i>Branta canadensis</i>)	1.8% (19/1061)
		Pink-footed goose (<i>Anser brachyrhynchus</i>)	1.3% (1/75)
Brant goose (<i>Branta bernicla</i>)		1.2% (1/84)	
Greater white-fronted goose (<i>Anser albifrons</i>)		0.6% (2/350)	
Swans (<i>Cygnus</i>)	Black swan (<i>Cygnus atratus</i>)	9.5% (6/63)	
	Whooper swan (<i>Cygnus cygnus</i>)	9.3% (169/1818)	
	Mute swan (<i>Cygnus olor</i>)	7.6% (931/12268)	

IS HPAI REALLY DECREASING IN WILD BIRDS?

MIGHT IT BE NECESSARY TO UPDATE THE FIFTY WILD BIRD SPECIES TARGETED FOR PASSIVE SURVEILLANCE?

CAN HPAI SURVEILLANCE BE IMPROVED?

(2nd slide). FIFTY WILD BIRD SPECIES TARGETED FOR PASSIVE SURVEILLANCE OF H5 HPAI IN THE EU
(from EFSA-ECDC-EURL scientific report AVIAN INFLUENZA OVERVIEW September – November 2017)

Family	Subfamily, tribe, or genus	Species	% positive (no. positive / no. tested)
Grebes (Podicipedidae)		Black-necked grebe (<i>Podiceps nigricollis</i>)	79.9% (246/308)
		Great crested grebe (<i>Podiceps cristatus</i>)	8.5% (50/588)
		Little grebe (<i>Tachybaptus ruficollis</i>)	7.8% (6/77)
Storks (Ciconiidae)		White stork (<i>Ciconia ciconia</i>)	0.5% (5/911)
Herons (Ardeidae)		Eurasian bittern (<i>Botaurus stellaris</i>)	2.9% (1/35)
		Little egret (<i>Egretta garzetta</i>)	2.9% (2/69)
		Great white egret (<i>Egretta alba</i>)	0.9% (4/441)
		Grey heron (<i>Ardea cinerea</i>)	0.8% (40/5093)
Pelicans (Pelecanidae)		Dalmatian pelican (<i>Pelecanus crispus</i>)	27.5% (11/40)
		Great white pelican (<i>Pelecanus onocrotalus</i>)	9.5% (2/21)
Cormorants and shags (Phalacrocoracidae)		Great cormorant (<i>Phalacrocorax carbo</i>)	0.6% (12/2090)
Raptors (Accipitridae, Falconidae, Strigidae)		White-tailed eagle (<i>Haliaeetus albicilla</i>)	6.6% (28/426)
		Rough-legged buzzard (<i>Buteo lagopus</i>)	3.7% (1/27)
		Common buzzard (<i>Buteo buteo</i>)	1.1% (72/6307)
		Peregrine falcon (<i>Falco peregrinus</i>)	3.4% (10/297)
		Northern goshawk (<i>Accipiter gentilis</i>)	1.3% (8/616)
		Eurasian eagle-owl (<i>Bubo bubo</i>)	0.9% (3/340)
Coots, crakes, and rails (Rallidae)		Western swamphen (<i>Porphyrio porphyrio</i>)	6.7% (1/15)
Sandpipers (Scolopacidae) ^(b)		Green sandpiper (<i>Tringa ochropus</i>)	33.3% (1/3)
Gulls, terns, and allies (Laridae)		Great black-backed gull (<i>Larus marinus</i>)	13.8% (22/159)
		European herring gull (<i>Larus argentatus</i>) ^(a)	3.1% (66/2135)
		Mew gull (<i>Larus canus</i>)	0.8 (4/481)
		Black-headed gull (<i>Chroicocephalus ridibundus</i>)	0.7% (30/4075)
Corvids (Corvidae)		Eurasian magpie (<i>Pica pica</i>)	0.6% (7/1232)
Thrushes (Turdidae)		Fieldfare (<i>Turdus pilaris</i>)	0.5% (1/192)

NEED FOR AN ECOLOGICAL APPROACH TO THE STUDY OF HPAI EPIDEMIOLOGY IN WILD BIRDS IN THE WESTERN PALAEARCTIC REGION

Can Preening Contribute to Influenza A Virus Infection in Wild Waterbirds?

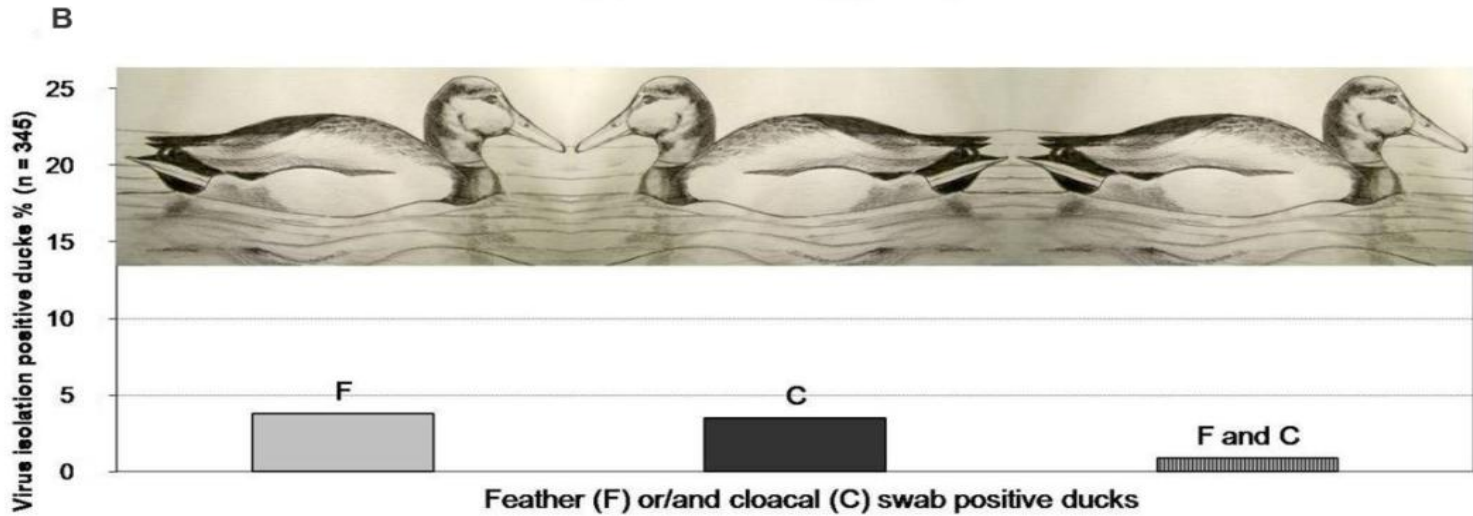
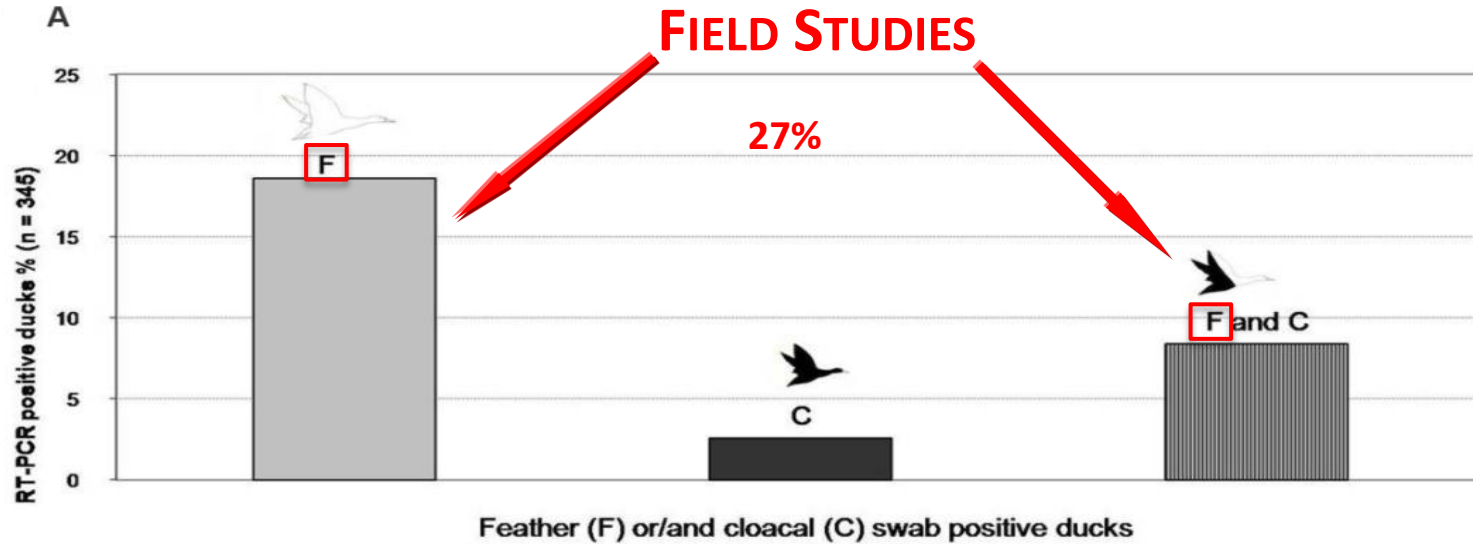
Mauro Delogu^{1*}, Maria A. De Marco², Livia Di Trani³, Elisabetta Raffini⁴, Claudia Cotti¹, Simona Puzelli², Fabio Ostanello¹, Robert G. Webster⁵, Antonio Cassone², Isabella Donatelli²

¹ Department of Veterinary Public Health and Animal Pathology, Faculty of Veterinary Medicine, University of Bologna, Ozzano Emilia, Italy, ² Department of Infectious, Parasitic and Immune-Mediated Diseases, Istituto Superiore di Sanità, Rome, Italy, ³ Department of Food Safety and Veterinary Public Health, Istituto Superiore di Sanità, Rome, Italy, ⁴ Istituto Zooprofilattico Sperimentale della Lombardia e dell'Emilia-Romagna, Lugo, Italy, ⁵ Division of Virology, Department of Infectious Diseases, St. Jude Children's Research Hospital, Memphis, Tennessee, United States of America



***Looking for
missing links in
Evian influenza
ecology***

***FROM THE ENVIRONMENT TO
BIRDS: A PREENING-MEDIATED
VIRUS CIRCULATION WAY***



$10^{4.6}$ EID₅₀/g

A NEW PERSPECTIVE FOR AVIAN INFLUENZA SURVEILLANCE

Italian Journal of Public Health, 2012, Volume 9, N. 2
<https://ijphjournal.it/article/view/6338/5985>

Human and animal integrated influenza surveillance: a novel sampling approach for an additional transmission way in the aquatic bird reservoir

Mauro Delogu, Maria A. De Marco, Claudia Cotti, Livia Di Trani, Elisabetta Raffini, Simona Puzelli, Robert G. Webster, Antonio Cassone, Isabella Donatelli



How to improve surveillance sampling for viruses stuck to the body surface

RESULTS: virologic and serologic results indicated that through self- and allopreening all the birds **experimentally coated** with the **preen oil/AIV mix** and the **control duck** ingested viruses covering feathers and became infected. **Virus isolation from feathers was up to 32 days post-coating treatment.**

The *Podicipediformes* role in avian influenza ecology: IS THEIR FEATHER-EATING BEHAVIOUR A NATURAL MECHANISM ALLOWING NEW OUTBREAKS?

J. Wildl. Dis. 2015, 51(1):290-3. <https://doi.org/10.7589/2014-05-126>

Isolation of type A influenza viruses from Red-necked Grebes (*Podiceps grisegena*)

Lebarbenchon C, Wilcox BR, Poulson RL, Slusher MJ, Fedorova NB, Katzel DA, Cardona CJ, Knutsen GA, Wentworth DE, Stallknecht DE

Abstract

“Six type-A low pathogenic influenza viruses from 14 Red-necked Grebes (*Podiceps grisegena*) from Agassiz National Wildlife Refuge were sequenced. The grebe viruses were closely related to North American duck viruses. The genetic and temporal subtype consistency between the duck and grebe isolates suggest spillover events, potentially enhanced by feather eating”

(<https://pubmed.ncbi.nlm.nih.gov/25380358/>)

Great-crested Grebe (*Podiceps cristatus*)



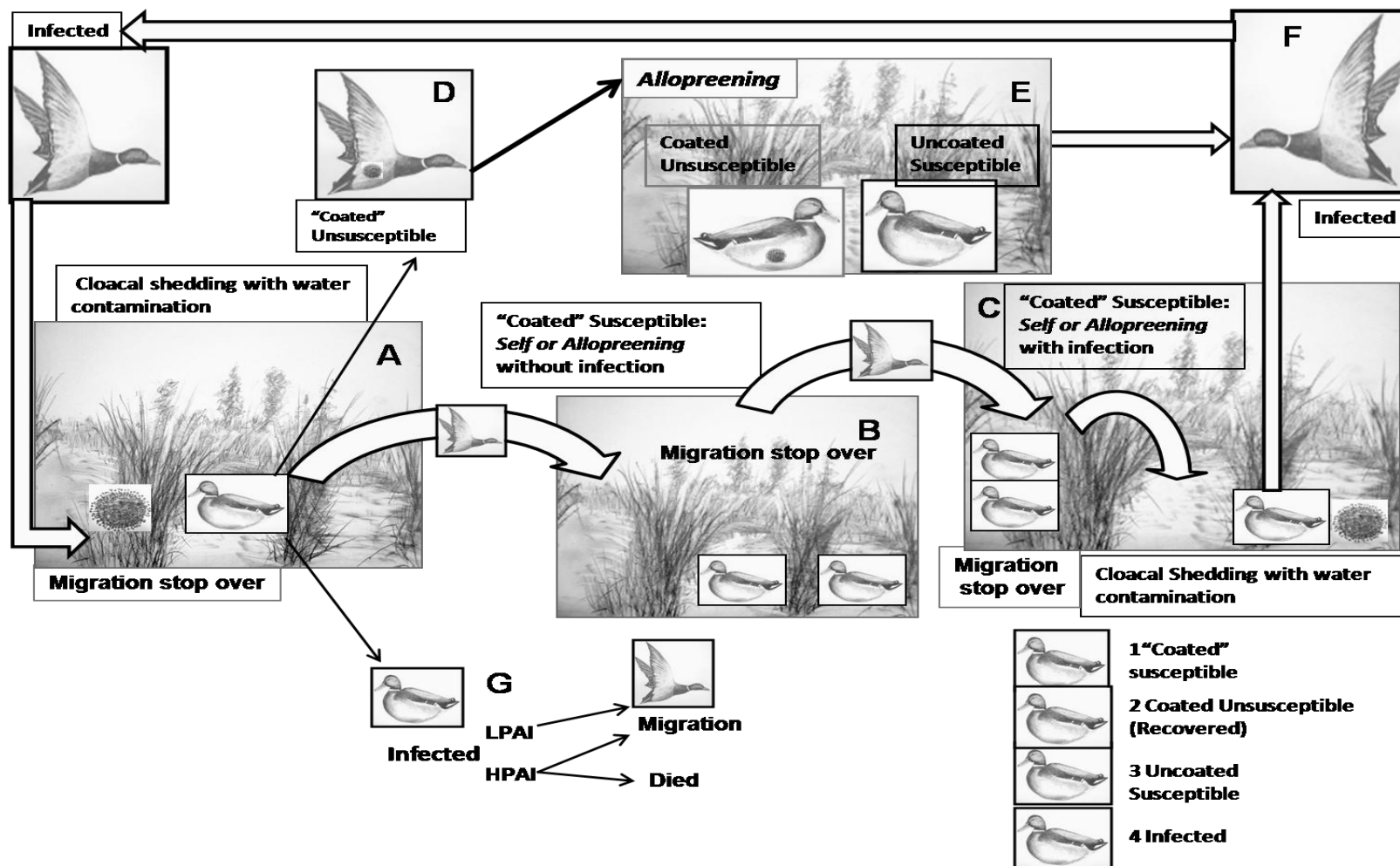
Image by Frank.Vassen - [CC BY 2.0](https://creativecommons.org/licenses/by/2.0/)

Red-necked Grebe (*Podiceps grisegena*)



Image by Larry Meade - [CC BY-NC-SA 2.0](https://creativecommons.org/licenses/by-nc-sa/2.0/)

VIRUS COATED BODY SURFACES: CAN UNINFECTED BIRDS SPREAD HPAIVS?





ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA



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e la Ricerca Ambientale



Sistema Nazionale
per la Protezione
dell'Ambiente

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